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CIVIL EFFECTS STUDY

CAMDEN–DELAWARE VALLEY AREA (ARMS-II)

R. B. Guillou

Issuance Date: July 10, 1963

CIVIL EFFECTS TEST OPERATIONS
U.S. ATOMIC ENERGY COMMISSION

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PRINTED IN USA
Price $0.50. Available from the Office of Technical Services, Department of Commerce, Washington 25, D. C.

USAEC Division of Technical Information Extension, Oak Ridge, Tennessee

CAMDEN-DELAWARE VALLEY AREA (ARMS-II)

By

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Santa Barbara, California
November 10, 1961

ABSTRACT

An Aerial Radiological Measuring Survey (ARMS) of the Camden–Delaware Valley area was made for the Civil Effects Test Operations, Division of Biology and Medicine, U. S. Atomic Energy Commission, by Edgerton, Germeshausen & Grier, Inc., between Sept. 4 and Oct. 16, 1961. The survey was part of a nationwide program to measure present environmental levels of gamma radiation. Approximately 6000 traverse miles were flown, at an altitude of 500 ft above the ground, in the area which consists of a 50-mile square centered on Camden, N. J., the part of New Jersey south of this square, and a strip about 15 miles wide southwest of Delaware Bay. The EG&G ARMS-II instrumentation was used in the survey.

The data are presented in aeroradioactivity units, or areas with similar gamma radiation rates at 500 ft, at two map scales: (1) generalized at about 1:1,000,000 and (2) detailed at 1:250,000. The aeroradioactivity in the area is less than 800 counts/sec except for four small areas in the northwest part of the area where it is less than 1200 counts/sec. In most of the New Jersey and Delaware parts of the area, the radioactivity is less than 400 counts/sec.

Aerial measurements of ground radioactivity in the ARMS-II Camden–Delaware Valley area were everywhere consistent with what was expected, considering the geology of the area. The south part of the area has a low radioactivity, and the surficial materials are mostly sands and gravels, which are commonly weakly radioactive. The north part of the area is slightly more radioactive, which would be expected from the types of sedimentary, igneous, and metamorphic rocks exposed there. Artificial radionuclides are probably present in only small quantities because the maximum background gamma radioactivity in many places is less than 200 counts/sec.

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CAMDEN–DELAWARE VALLEY AREA (ARMS-II)

1 INTRODUCTION

1.1 Location of Area

An Aerial Radiological Measuring Survey (ARMS) of the Camden–Delaware Valley area was made for the Civil Effects Test Operations (CETO), Division of Biology and Medicine, U. S. Atomic Energy Commission, by Edgerton, Germeshausen & Grier, Inc. (EG&G), between Sept. 4 and Oct. 16, 1961. The area surveyed is about 70 miles wide (east-west) and 120 miles long (north-south) and lies between 74°37′ and 75°53′ West longitude and 38°32′ and 40°17′ North latitude (Fig. 1). The area consists of a 50-mile square, centered on Camden, N. J., the part of New Jersey south of this square, and a strip about 15 miles wide southwest of Delaware Bay. Included in the area are parts of New Jersey, Pennsylvania, Delaware, and Maryland and the cities of Philadelphia, Camden, Trenton, Wilmington, and Dover.

1.2 Purpose of Survey

The ARMS-II Camden–Delaware Valley survey was one of many that have been flown for the CETO since the nationwide ARMS program was started (1958). Figure 2 shows the location of the areas that have been surveyed to date. The purpose of the program is to measure the present environmental levels of gamma radiation in areas around nuclear facilities and planned nuclear activities. It is desirable to document the environmental radiation, which results primarily from the natural radioactivity of the surface soil and rock, to establish a base line or environmental datum. ARMS data from selected areas, in conjunction with data from resurveys of these areas, can be used to appraise changes in environmental levels of radiation brought about by debris from nuclear weapons testing programs, operation of nuclear facilities, and radiation accidents. The data are also important to an understanding of the long-term biological effects of low-level radiation.

1.3 Air-borne Survey Procedure

Topographic maps for the ARMS-II Camden–Delaware Valley area were laid out, and the boundaries of the area were determined. Flight lines were drawn in a north-south direction about 1 mile apart.

Ground check points were then selected along the flight lines and at the ends of the flight lines in order that aircraft-position information obtained along the flight path could be correlated to the maps of the area.

The survey flights in the Camden–Delaware Valley area were conducted between Sept. 4 and Oct. 16, 1961. About 6000 traverse miles were flown.

The daily flight procedure included equipment-stabilization time and in-flight calibrations on the radiation-detection apparatus. As soon as the aircraft was air-borne, the equipment was turned on and was allowed to reach temperature equilibrium. When thermal stabilization of the circuity was reached, the radiation apparatus was calibrated with a Cs^{137} source. Measurements of air-borne, cosmic, and extraneous radiation were then taken at 3000 ft above terrain. After arriving at the initial survey line for the day, the aircraft descended to the

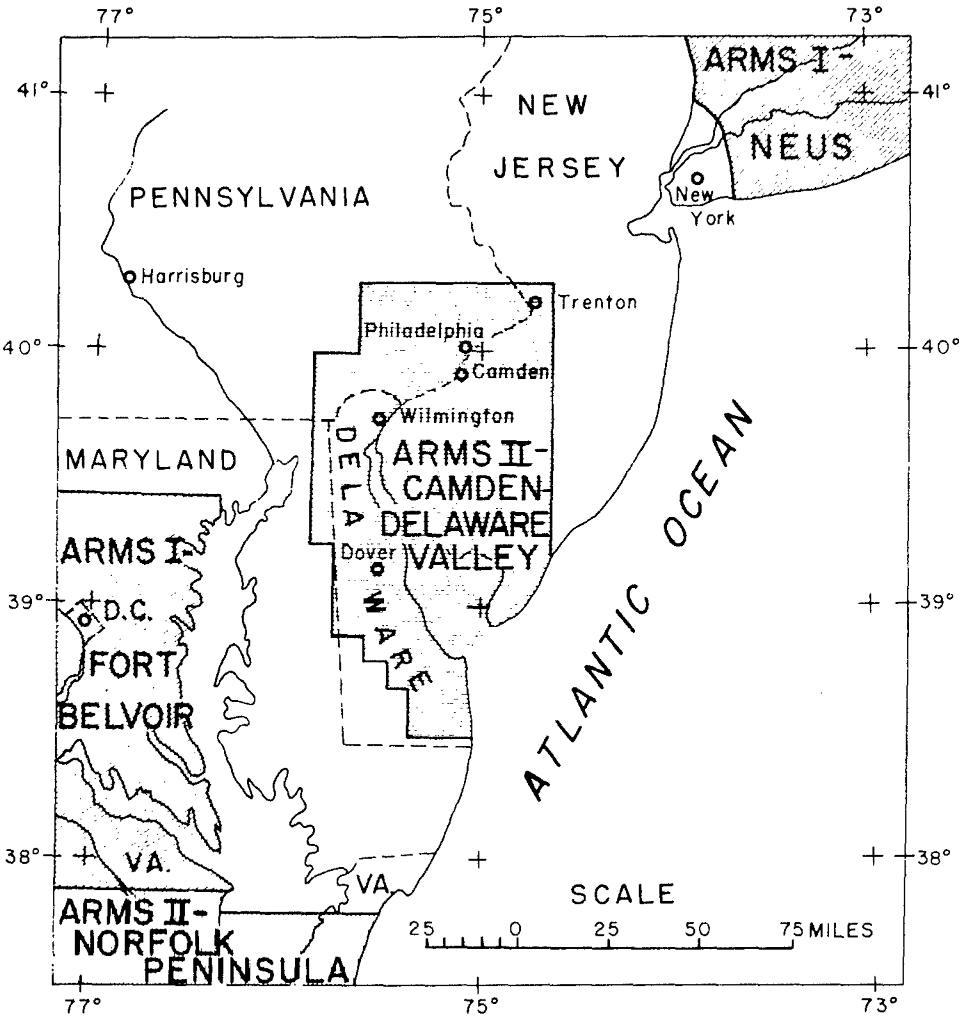


Fig. 1—Index map showing location of ARMS-II Camden–Delaware Valley area and adjacent ARMS areas.

500-ft survey altitude, and the value of the undesirable radiation, as measured at 3000 ft, was set into the radiation computer. The radiation data taken as the aircraft progressed down the survey line represented net terrestrial gamma radiation. During the survey flight each day, the radiation-detection apparatus was periodically calibrated to keep the drift in the detection system to a minimum.

Upon completion of each flight, the data tapes were removed from the aircraft and were immediately edited by the flight personnel. Pertinent information, such as missing or obliterated ground check points, new points selected during flight, and equipment malfunctions, was immediately related to map locations and the radiation data. The corrected data were then entered onto the area working maps.

1.4 Instrumentation

The EG&G ARMS-II instrumentation was installed in a Beech model 50 twin Bonanza, N702B. The apparatus consists of three subsystems (Fig. 3): (1) the radiation-detection and -measurement subsystem; (2) the aircraft space-positioning subsystem, and (3) the information printout subsystem. The functions of these subsystems and their components are described in detail[1] in EG&G Report S-26.

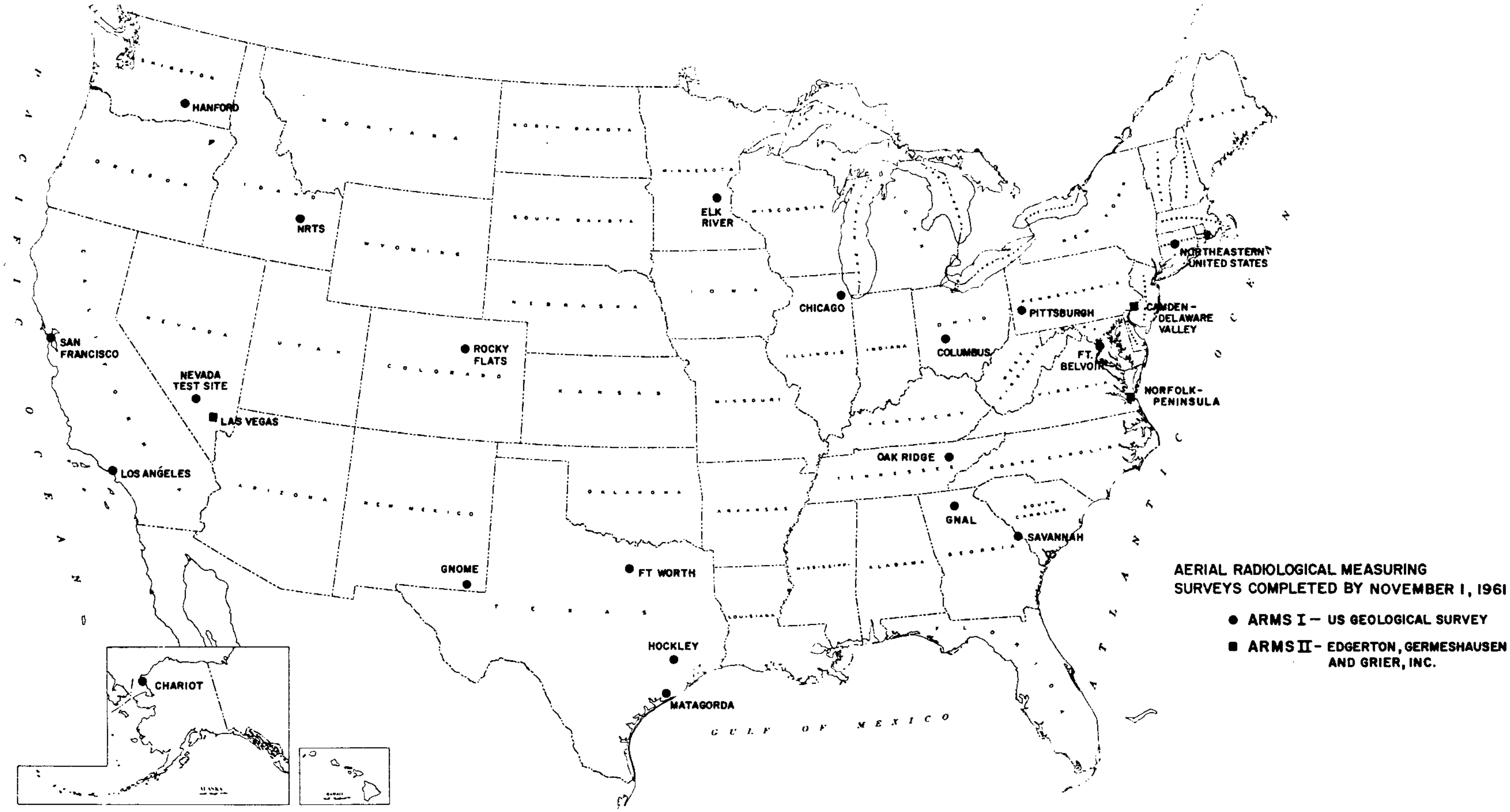


Fig. 2—Civil Effects Test Operations ARMS program.

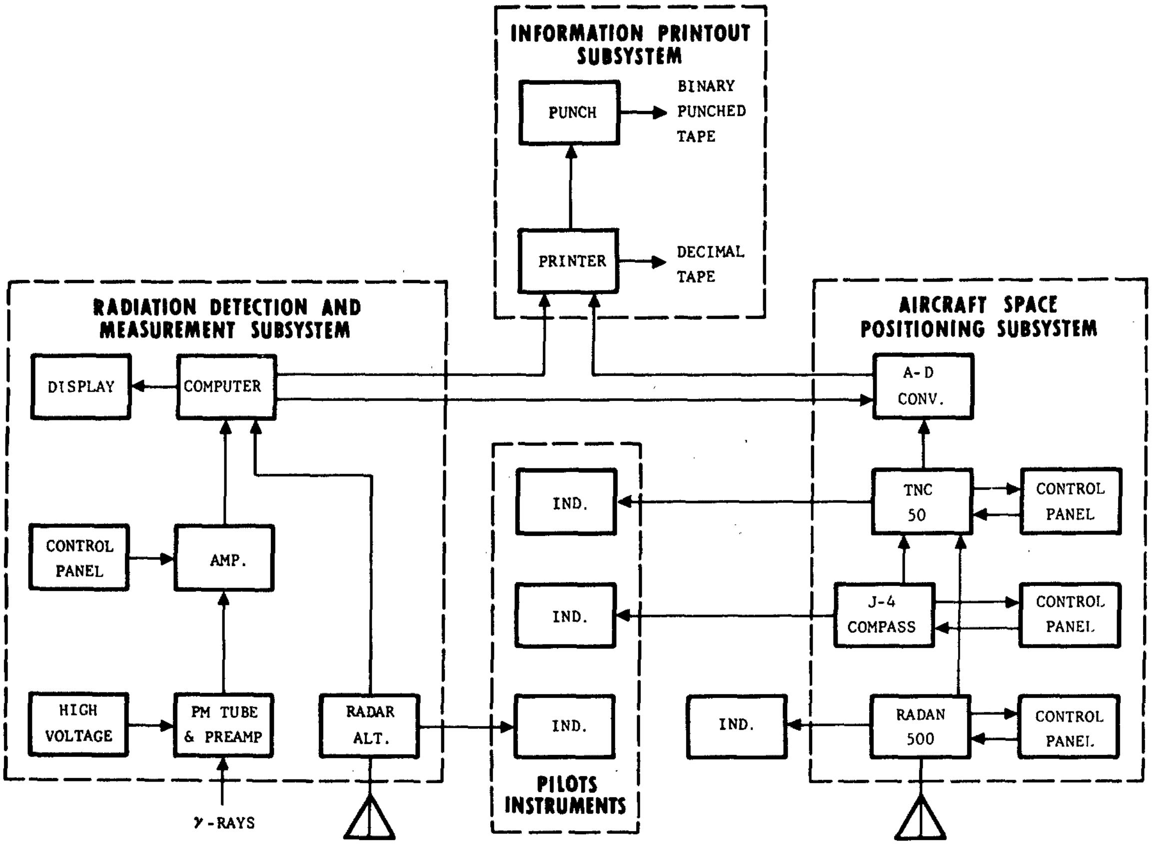


Fig. 3—Diagram of EG&G ARMS-II instrumentation.

The main detection unit utilizes a 9-in.-diameter 3-in.-thick thallium-activated sodium iodide crystal and a 12-in. photomultiplier tube. The radiation amplifier unit consists of a voltage amplifier, a pulse shaper, and an energy discriminator that is set to reject pulses due to gamma rays with energies below 50 kev for routine surveying and 662 kev for calibration purposes. The arithmetic computer performs the cosmic background correction, the compensation of the data for deviations from the nominal surveying altitude, and the classification of count rate into channels and gives print command signals to the information printout subsystem. The correction for cosmic and other undesirable background consists of subtracting from the gross count, at 500 ft above the ground, a count rate equal to the undesirable background; this gives the net count. This background is normally measured at 3000 ft above the ground. Compensation of the data for deviations from the nominal surveying altitude was accomplished through control of the sampling period by the introduction of a signal from the radar altimeter. The normal sampling period was 1 sec. The sampling period was less than 1 sec when the aircraft was below 500 ft and greater than 1 sec when the aircraft was more than 500 ft above the ground. The count rate was normalized to 500 ft above the ground in the range from 300 to 900 ft above the ground. The arithmetic computer classifies the count rate into digital channels of predetermined width. In the range of most natural materials, between 0 and 2000 counts/sec, the channel width is narrow; above 2000 counts/sec a progressively wider channel width is used.

The position of the aircraft was determined by a modified General Precision Laboratories Doppler navigation system. The J-4 compass system establishes a reference line against which the actual path of the aircraft is compared, the heading information being held by either a driven gyro or a magnetically slaved gyro. The RADAN 500 Doppler radar unit determines the ground speed and drift angle of the aircraft relative to the J-4 reference line. Signals from the J-4 compass and the RADAN 500 go to the TNC-50 (track navigation computer), where the along-track and the across-track distances relative to an initial ground point are computed.

The along-track and the across-track distance signals then go to the analog-to-digital converter. Upon receipt of a print command from the radiation computer, these outputs go to the printer and are recorded.

The information printout subsystem consists of two data recorders: (1) a decimal printer and (2) a binary tape punch. The data recorded are: survey leg number, radiation channel, along-track distance, across-track distance and direction, and detector sensitivity. Since the radiation-detection subsystem also contains a small crystal that is used in high-intensity fields, it was necessary to record which detector was in use during collection of the data.

2 THEORETICAL CONSIDERATIONS OF ARMS DATA

2.1 Sources of Gamma Rays

The gamma-ray activity that is measured by ARMS equipment at 500 ft above the ground has three principal origins: (1) cosmic radiation; (2) atmospheric sources, or the radionuclides in the air; and (3) terrestrial sources, which are the radionuclides in the surficial materials of the earth. It is not possible to measure directly the relative contribution of each source at a particular time while surveying, but certain assumptions and calibration procedures permit good estimates of the components of the gross gamma radiation to be made. A detailed discussion of sources of gamma rays is included in Uses of ARMS Data.[2] The following paragraphs present a brief summary of the most important of the gamma-ray sources that affect ARMS data.

The cosmic radiation component at 500 ft above the ground is due mainly to the air-scattered gamma rays that are induced by cosmic particles. The count rate at 3000 ft above the ground, where negligible radiation from the ground is present, is considered to be due to the cosmic component, the atmospheric sources, and the extraneous radiation. This contribution was measured each day while the ARMS flights were being conducted and was subtracted from the gross count at 500 ft above the ground to give the recorded net count rate. The average 3000-ft background during the ARMS-II Camden–Delaware Valley survey was about 1050 counts/sec; of this amount 800 counts/sec was due to the calibration source in the aircraft.

The component of the gamma-ray activity at 500 ft above the ground which is due to radionuclides in the atmosphere cannot be separated directly from the terrestrial or cosmic components. Measurements of the artificial and natural radionuclides in ground-level air, however, have been made for several years by various investigators, and these measurements indicate that the contribution of atmospheric sources (principally radon daughter products) to the total count rate is normally insignificant. Abnormal situations occur during periods of severe inversion or immediately after testing of nuclear devices. When fission products are present in the air, they are assumed to be uniformly distributed; therefore their contribution to the count rate is removed with the cosmic background.

The terrestrial component of the gamma radiation found at 500 ft above the ground comes from the radionuclides in the surficial 12 in. of earth materials. Radionuclides in soil and, to a lesser extent, in rock are the major sources of gamma rays. Artificial radionuclides are generally concentrated in the surficial inch or two of material and, as is described later, probably have little effect on the distribution of aeroradioactivity units in the Camden–Delaware Valley area. The present distribution of the surficial material and the concentrations of natural radionuclides in it are determined by the original content and form of the radioactive material in the parent rock and by changes brought about by geologic and pedologic processes.

The principal natural gamma-producing radionuclides found in rocks and soils are K^{40} and the members of the uranium and thorium series. The content of these radionuclides in various rocks is shown in Table 1.

There is a general trend for the content of these radionuclides in igneous rocks to increase with increasing silica content. Among the sedimentary rocks, shales are generally more radioactive than sandstones and carbonate rocks. The natural radioactivity of metamorphic rocks, unless radionuclides were added or removed during metamorphism, reflects

TABLE 1—K^{40}, THORIUM, AND URANIUM IN IGNEOUS AND SEDIMENTARY ROCKS
(in parts per million)

	K^{40}		Thorium		Uranium	
	Average	Range	Average	Range	Average	Range
Igneous rocks:						
Basaltic	0.8	0.2 to 2	4.0	0.5 to 10	1.0	0.2 to 4
Granitic	3.0	2 to 6	12	1 to 25	3	1 to 7
Sedimentary rocks:						
Shales	2.7	1.6 to 4.2	12	8 to 18	3.7	1.5 to 5.5
Sandstones	1.1	0.7 to 3.8	1.7	0.7 to 2.0	0.5	0.2 to 0.6
Carbonates	0.3	0 to 2	1.7	0.1 to 7	2.2	0.1 to 9

the potassium, uranium, and thorium content of the original sedimentary or igneous rock. The concentrations of the natural radionuclides in soils are probably similar to the concentrations in sedimentary rocks because both are produced by the breakdown of preexisting rocks. The fine clayey and silty soils are generally more radioactive than coarser sandy soils because much of the soil radioactivity results from radioelements that are fixed or absorbed on clay. The interaction of various soil-forming processes, however, sometimes produces a concentration of radioactive accessory minerals and therefore an increase in total radioactivity in the surficial soil.

2.2 Effect of Meteorological Conditions on Gamma-ray Flux from Terrestrial Sources

Changes in meteorological conditions have only a small effect on the gamma-ray flux at 500 ft which is produced by terrestrial sources. This subject is treated in detail in Ref. 3. The largest effect is caused by changes in the density of the air between the detector and the ground. The most important factor here, of course, is that of temperature variations. A temperature deviation of ±10°F would create a maximum variation in count rate of ±3 per cent. The effect of air-pressure variations on the uncertainty in the data is negligible. The change in air pressure of ±8 mm would introduce an error of only 0.15 per cent in the count rate. Changes in relative humidity also have a small effect on the attenuation of gamma rays. If survey operations were proceeding at 80°F at 500 ft and the relative humidity were 50 per cent, the error that a change of ±50 per cent in the relative humidity would introduce into the data would be about 0.9 per cent. The meteorological parameters of humidity, temperature, and pressure were recorded for each survey day, but, since their combined effect on the radiation levels is small, they were not used in the present application of the data. They are available, however, if a more detailed analysis of the data is required at some future time.

2.3 Conversion of Count Rate to Dose Rate

The EG&G ARMS-II instrumentation was designed to give data that are compatible with the data of the existing United States Geological Survey ARMS-I equipment. Both units were flown over the Extended Source Calibration Area at the Nevada Test Site for cross-calibration purposes. The calibration range consisted of 400 equal-valued sources spaced on 100-ft centers to form a square that was 2000 ft on a side. The central source in the area was replaced by 100 smaller sources, spaced on 10-ft centers, the total intensity of which equaled that of the replaced source. The results of the flight measurements are being reported by F. J. Davis, Oak Ridge National Laboratory.[4]

The gamma dose rate 3 ft above terrain in the center of the area was measured by R. M. Johnson of Oak Ridge National Laboratory. The results of Johnson, combined with the EG&G ARMS-II data taken at 500 ft above terrain, give the following conversion factors:

Co^{60} gammas: 22 counts/sec at 500 ft = 1 μr/hr at 3 ft

Cs^{137} gammas: 25 counts/sec at 500 ft = 1 μr/hr at 3 ft

These figures should be applied to ARMS-II survey data with caution since any individual reading obtained with the ARMS-II equipment represents a radiation intensity that is integrated over a ground area approximately 900 ft in radius. In addition, no information is available concerning the energy of the radiation detected during survey operations. In view of these uncertainties and the small difference between the conversion factors for different gamma energies, a single conversion factor is recommended:

25 counts/sec at 500 ft = 1 μr/hr at 3 ft

3 AERORADIOACTIVITY DATA

3.1 Interpretation and Compilation

The present manual reduction of ARMS-II data from the decimal tape which was obtained during the survey to the aeroradioactivity units map, the form in which the data are presented, required two interpretation and two compilation steps.

The first step consisted in editing the decimal tape by selecting the data points that divide the flight lines into segments having similar radioactivity and the points that indicate known locations on the flight maps or major changes in flight path. The flight line was divided into segments because aeroradioactivity data for the ARMS-II Camden–Delaware Valley area consisted of more than 50,000 data points. The distribution of radioactivity on the ground is such that a range in count rate is usually recorded on any segment of a flight line. If an area on the ground has a uniform gross gamma radioactivity, it will have associated with it a narrow range in count rate. A nonuniform gross gamma radioactivity, such as the bands of different width with different radioactivity produced by alternating sandstone, shale, and limestone beds, gives rise to a wide range in count rate. The segments were chosen to show as much information about the radioactivity as is consistent with the 1 : 250,000 compilation scale.

The second step, a compilation process, consisted of plotting the selected data points on tracing paper at map scale (1 : 250,000). The recorded Doppler distances were used to plot the flight line.

In the third step the flight lines were corrected for instrumental error, and the true positions of the data points were plotted on the compilation map. The correction consisted of the graphical proportioning of the error between the map locations of the segment end points. The "Doppler error," or the difference between the map position and the Doppler-indicated position of an end point, was less than 0.5 per cent of the distance flown. However, after the "Doppler error" had been properly proportioned, the data points were accurate to within 0.1 mile, or 0.03 in. at map scale.

The final interpretative step in the reduction of the data was the delineation of aeroradioactivity units, or the selection of borders for areas having similar count rates on adjacent flight lines. Since the natural background radioactivity was commonly complex and since this detail was easily recorded by the ARMS instrumentation, the delineation of aeroradioactivity units put the data in a form that could be readily understood. The size of the units represents a compromise between the narrowest possible range in count rate and the largest possible area within one unit. Dissimilar count rates on adjacent lines, as well as fluctuations along a flight line, contributed to the width of the range of count rate for a particular aeroradioactivity unit. The upper limit of one unit may be the lower limit of an adjacent unit or the range of one unit may overlap the range of an adjacent unit. Since the data were prepared for presentation on a map at a scale of 1 : 250,000, or 4 miles equals 1 in., most of the units should be more than 2 miles wide (along the flight line) and should encompass more than four survey lines. Aeroradioactivity units as narrow as ½ mile are shown on the map if they differ substantially from adjacent units.

The aeroradioactivity data and units shown in Fig. 4 illustrate the philosophy and problems connected with the delineation of aeroradioactivity units. The numerical values listed

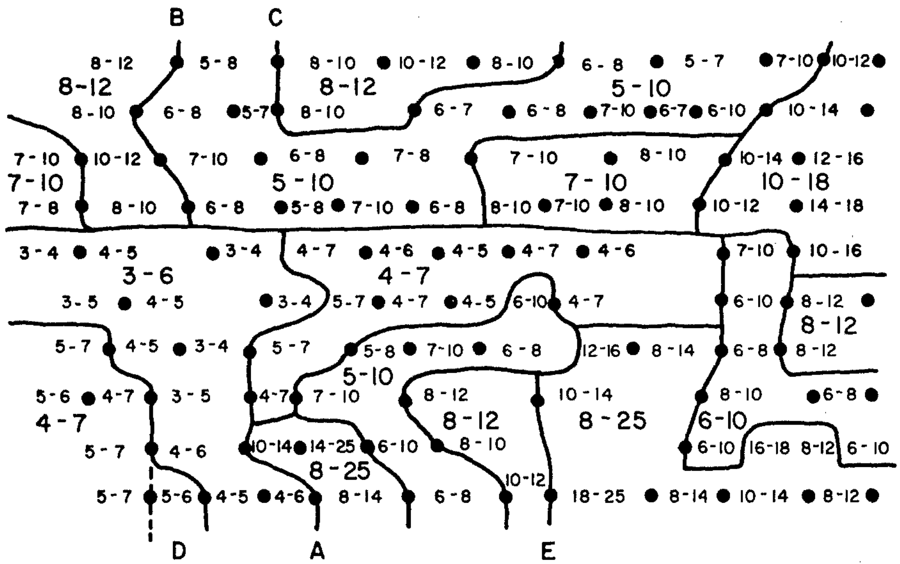


Fig. 4—Aeroradioactivity data and units (count rate in hundreds of counts per second).

represent gamma count rates in hundreds of counts per second. It can be seen that in many places the position of a unit boundary is unique and obvious, such as at A, B, and C. At other places, such as D, the placement of the boundary was arbitrary and the dashed line could have been used. The selected boundary was chosen to indicate a unit with a slightly lower radioactivity to the right of the line; a single unit (3-7) instead of three units (4-7, 3-6, and 4-7) could have been used in this region. At E a unit boundary was drawn through a fairly uniform segment (8-10). This arbitrary division of a segment is avoided if possible, but it sometimes is necessary to simplify the shape of units while holding the range of units as narrow as possible. The 8-25 unit to the right of E is an example of a complex area that required a wide range in count rate to avoid a multitude of small units.

3.2 Presentation of Aeroradioactivity Data

Aeroradioactivity data for the ARMS-II Camden–Delaware Valley area are presented in two forms: (1) a page-size generalized version at a scale of about 1 : 1,000,000 (16 miles equals 1 in.) (see Fig. 5); and (2) a full-size version at a scale of 1 : 250,000 (4 miles equals 1 in.) (see Plates 1, 2, and 3 in pocket for detailed study).

3.2.1 Generalized Aeroradioactivity Data

Three patterns are used in Fig. 5 to denote the generalized aeroradioactivity data for the area: areas where the maximum radioactivity was (1) mostly less than 400 counts/sec, (2) less than 800 counts/sec, and (3) less than 1200 counts/sec. Only the gross features are shown in this figure; aeroradioactivity unit boundaries have been smoothed, and small units have been deleted.

The radioactivity of the ARMS-II Camden–Delaware Valley area is less than 800 counts/sec except for four small areas in the northwest part of the area where the maximum count rate is less than 1200 counts/sec. In most of the New Jersey and Delaware parts of the area, the radioactivity is less than 400 counts/sec. If the qualifications mentioned in Sec. 2.3 are borne in mind, these measurements indicate that the ground dose rate due to terrestrial gamma

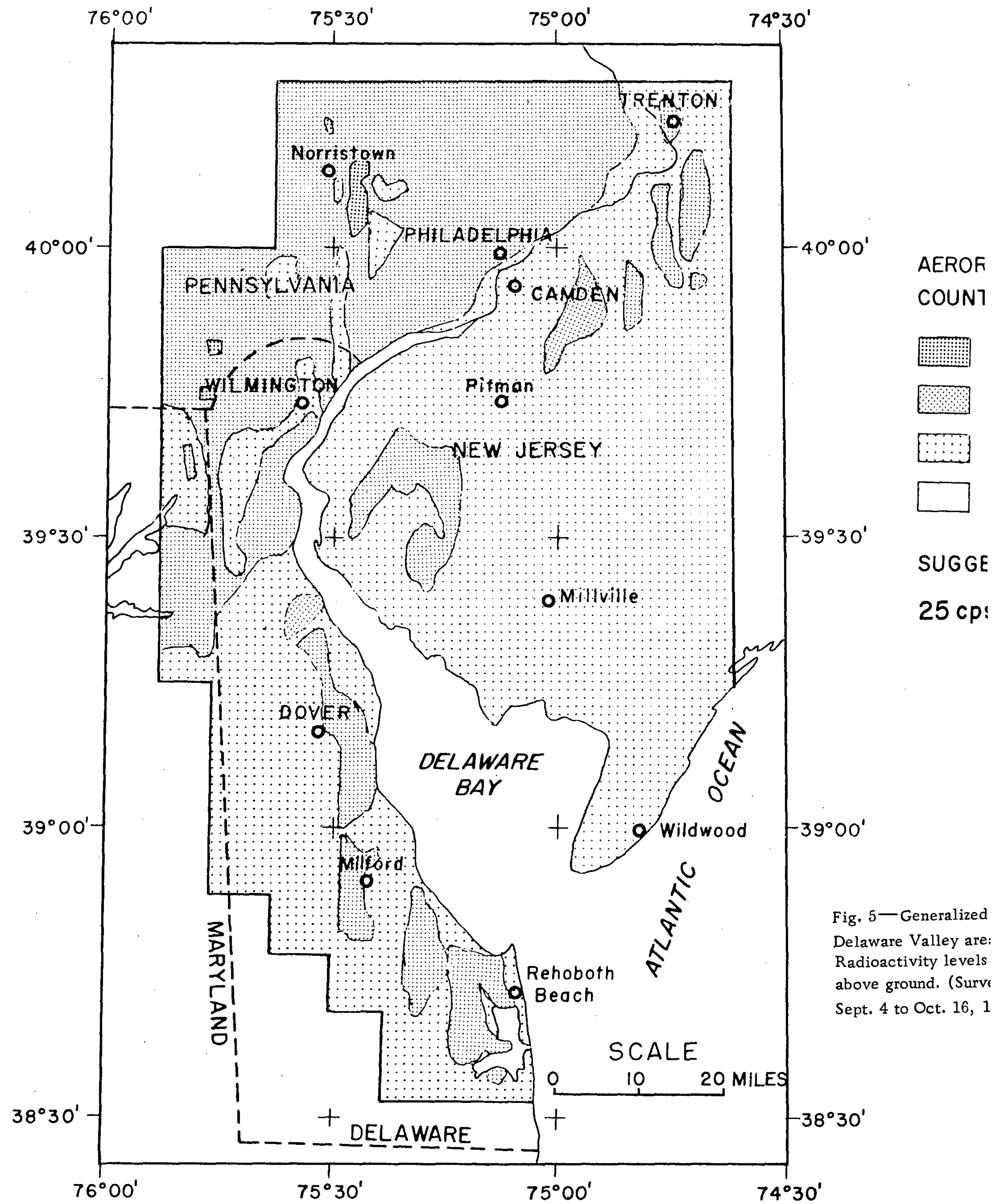


Fig. 5—Generalized
Delaware Valley are
Radioactivity levels
above ground. (Surv
Sept. 4 to Oct. 16, 1

(1)

40°00'

AERORADIOACTIVITY IN
COUNTS PER SECOND :

LESS THAN 1200

LESS THAN 800

LESS THAN 400

UNSURVEYED AREA

9°30'

SUGGESTED CONVERSION FACTOR

25 cps at 500' = 1 μr/hr at 3'

9°00'

Fig. 5—Generalized aeroradioactivity map of the ARMS-II Camden–Delaware Valley area (New Jersey, Pennsylvania, Delaware, and Maryland). Radioactivity levels in counts per second normalized to 500 ft above ground. (Survey by Edgerton, Germeshausen & Grier, Inc., Sept. 4 to Oct. 16, 1961.)

8°30'

2

radioactivity in the Camden–Delaware Valley area is less than 48 μr/hr and in much of the area is less than 16 μr/hr.

3.2.2 Detailed Aeroradioactivity Data

The detailed aeroradioactivity units in the ARMS-II Camden–Delaware Valley area are shown on Plates 1 through 3: the north part is shown on Plate 1; the center part is shown on Plate 2; and the south part is shown on Plate 3. These maps are printed so that the entire area can be studied by putting the three maps together without trimming. Topography and more-detailed cultural information for the area can be obtained from the Newark, Salisbury, and Wilmington sheets, Topographic Maps of the United States, 1:250,000 scale series; these maps are available from the U. S. Geological Survey.

4 CORRELATION OF AERORADIOACTIVITY UNITS

The general distribution of the terrestrial radioactivity in the ARMS-II Camden–Delaware Valley area can be directly attributed to the geology of the area. It is believed that a detailed study of the surficial geologic materials in the area would provide reasons for most of the aeroradioactivity units. To a large extent, the terrestrial gamma radioactivity in the urban areas is probably a consequence of the building and road materials used in these areas. Artificial radionuclides are probably present in only small quantities because the maximum background radioactivity in many places is less than 200 counts/sec. The distribution of artificial radionuclides in the area is assumed to be uniform.

4.1 Correlation of Aeroradioactivity Units with Geology

The general radioactivity of the ARMS-II Camden–Delaware Valley area, as shown in Fig. 5, is a direct consequence of the geology of the area.[5,6,7] The rocks in the northern part of the area, where it is slightly more radioactive than the rest of the area, are Triassic sedimentary and igneous rocks and metamorphosed sedimentary and igneous rocks of the Piedmont province. These rocks would be expected to be generally more radioactive than the widespread quaternary sands and gravels and the sedimentary rocks of the Coastal Plain found in the rest of the area.

Specific correlations between individual aeroradioactivity units and geologic units were not noted in this brief study. This absence of specific correlations resulted from a combination of the following factors: (1) the small differences in the radioactivity of the bedrock materials, (2) the use of data from flight lines spaced 1 mile apart, and (3) the emphasis on environmental radioactivity rather than areal geology. Several slight changes in radioactivity which coincide with geologic boundaries are not shown on the aeroradioactivity maps because they add to the complexity of the maps without improving the usability of the radioactivity data.

4.2 Correlation of Aeroradioactivity Units with Other Sources

All the aeroradioactivity units in the ARMS-II Camden–Delaware Valley area are believed to result from the distribution of natural (not artificial) radionuclides in the surficial rocks and soils of the area.

5 SUMMARY AND CONCLUSIONS

The ARMS-II Camden–Delaware Valley area survey was the second operational survey of a large area with the EG&G ARMS-II instrumentation. The operating procedures developed and proved in this and the previous survey indicate that the system is extremely versatile, being capable of routine surveying on straight lines over areas of flat to moderate topography and for flying irregular individual traverses in mountainous terrain.

The radiation-detection and -measurement subsystem is sensitive to, and capable of recording, the environmental gamma background in a complex area where extremes of background

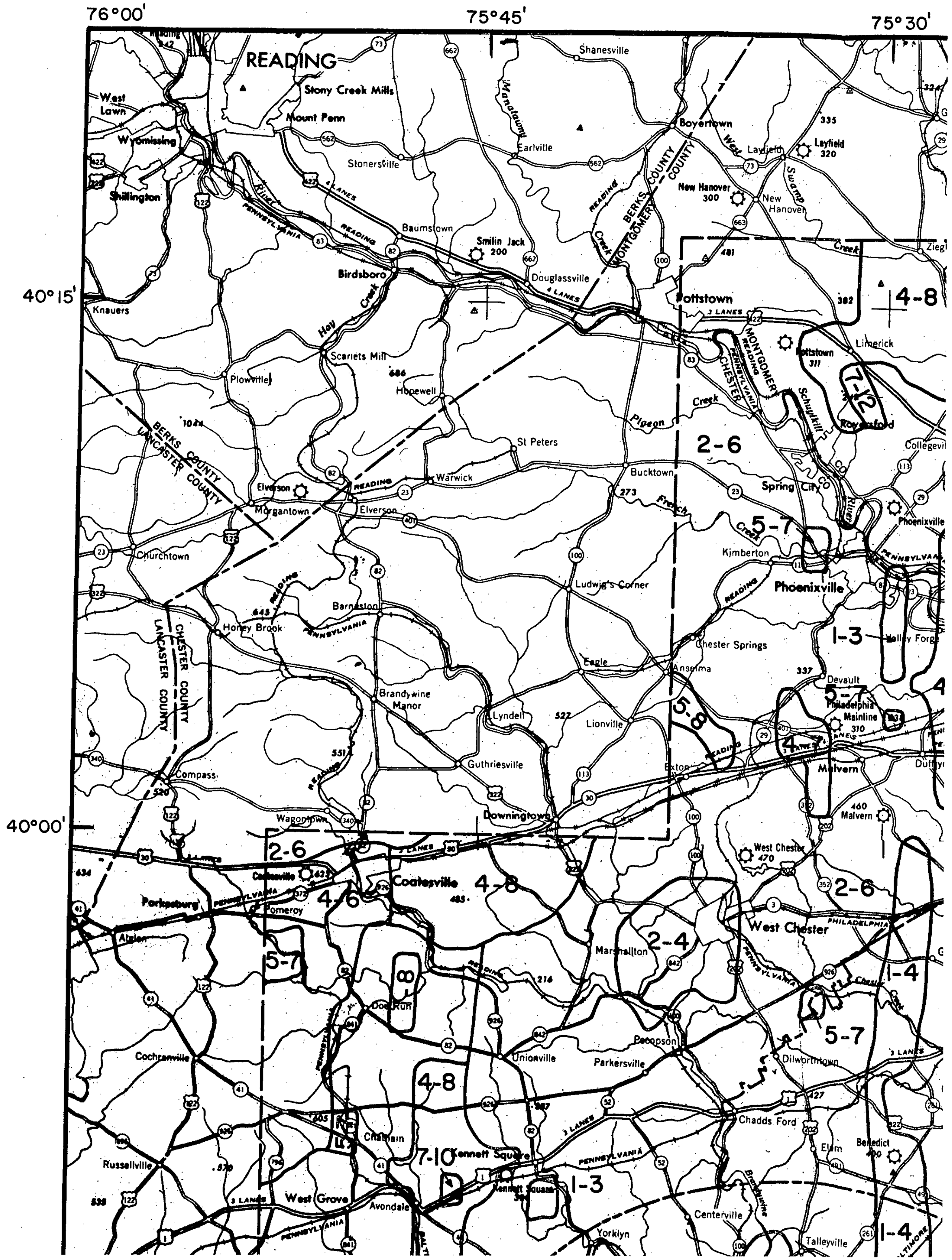
radiation are encountered. The aircraft space-positioning subsystem can furnish accurate geographic locations in areas of flat and rugged topography and on straight or irregular flight lines.

Manual techniques for the reduction of the digital radiation and geographic-position data have been developed to the point where data reduction can keep pace with surveying operations. Interpretation and reduction of the data are necessary to convert it to a form in which it can be presented on a map at a scale of 1:250,000 (or 4 miles equals 1 in.). The interpretation involves delineation of aeroradioactivity units or areas which have similar gamma radioactivity. Depending on the local complexity of the environmental gamma background radiation, these units can have a wide or narrow range in count rate.

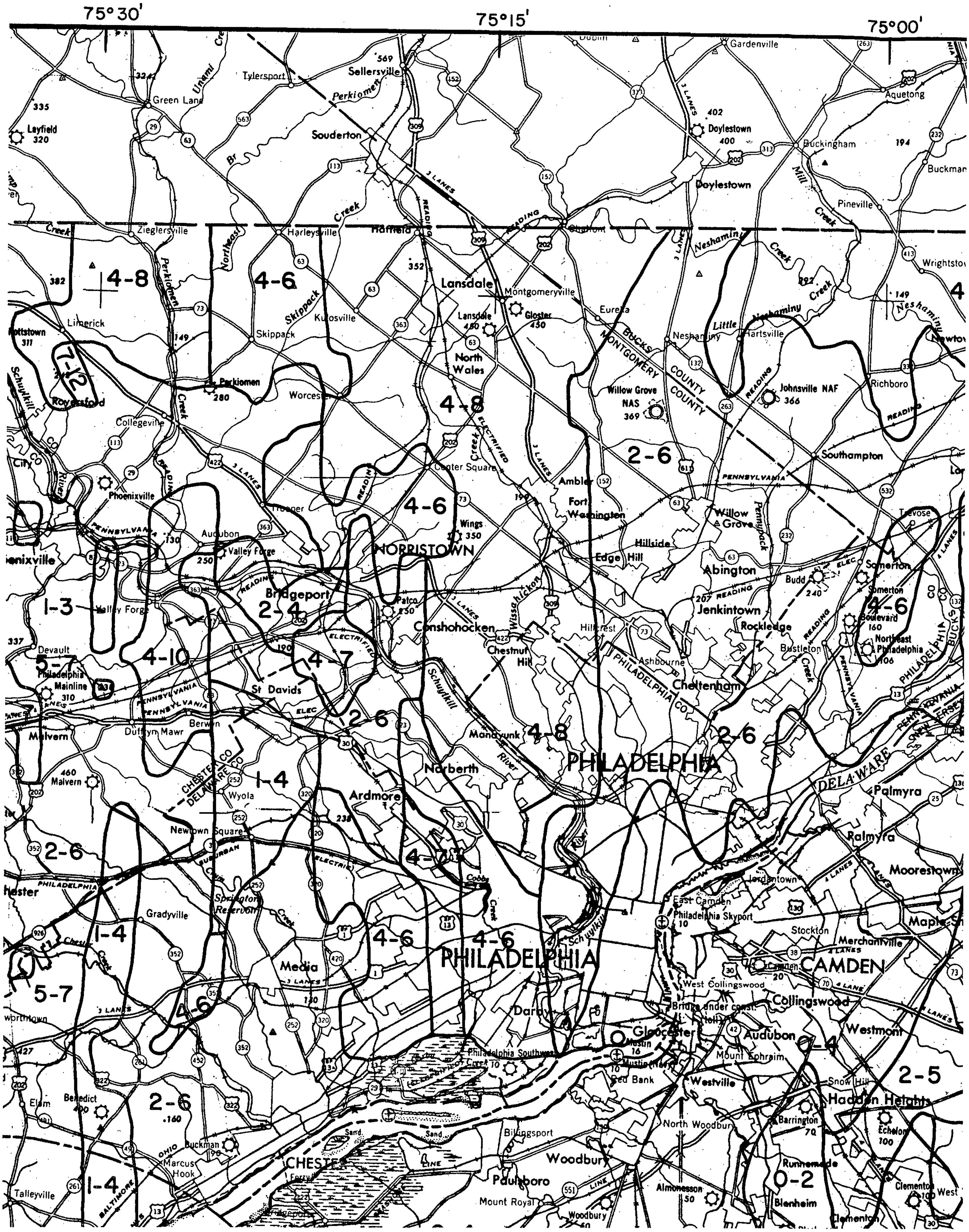
Aerial measurements of ground radioactivity in the ARMS-II Camden–Delaware Valley area are everywhere consistent with what would be expected, considering the geology of the area. The south part of the area has a low radioactivity, and the surficial materials in this part of the area are mostly sands and gravels, which are commonly weakly radioactive. The north part of the area is slightly more radioactive; this was expected because of the types of sedimentary, igneous, and metamorphic rocks exposed there.

REFERENCES

1. F. J. Davis and P. W. Reinhardt, *Extended- and Point-source Radiometric Program,* USAEC Report CEX-60.3, Oak Ridge National Laboratory (in preparation).
2. Edgerton, Germeshausen & Grier, Inc., *Uses of ARMS Data* (in preparation).
3. R. F. Merian, J. G. Lackey, and J. E. Hand, *Aerial Radiological Monitoring System. I. Theoretical Analysis, Design, and Operation of a Revised System,* USAEC Report CEX-59.4, 1960.
4. F. J. Davis, Oak Ridge National Laboratory (CEX report in preparation).
5. Carlyle Gray and V. C. Shepps, *Geologic Map of Pennsylvania,* Pennsylvania Topographic and Geologic Survey, 1960.
6. J. V. Lewis, H. B. Kümmel, and M. E. Johnson, *Geologic Map of New Jersey,* New Jersey Bureau of Geology and Topography, 1950.
7. I. W. Marine and W. C. Rasmussen, *Preliminary Report on the Geology and Ground-Water Resources of Delaware,* Delaware Geological Survey Bull. 4, 1955.



76°00'
75°45'
75°30'
40°15'
40°00'
READING
Stony Creek Mills
Mount Penn
West Lawn
Wyomissing
Shillington
Stonersville
Shanesville
Earlville
Manatawny
Boyertown
West Swamp
Laytield
Layfield 320
New Hanover 300
New Hanover
Baumstown
Smilin Jack 200
Birdsboro
Douglassville
Hay Creek
BERKS COUNTY
MONTGOMERY COUNTY
Pottstown
Pottstown 311
Limerick
Royersford
Knauers
Scarlets Mill
Plowville
Hopewell
St Peters
Warwick
Elverson
Morgantown
Bucktown
Pigeon Creek
French Creek
Spring City
Phoenixville
Collegeville
Kimberton
Churchtown
LANCASTER COUNTY
CHESTER COUNTY
Ludwig's Corner
Barneston
Honey Brook
Chester Springs
Eagle
Anselma
Brandywine Manor
Lyndell
Lionville
Guthriesville
Compass
Wagontown
Downingtown
Exton
Devault
Valley Forge
Philadelphia Mainline 310
Malvern
Malvern 460
West Chester 470
West Chester
Coatesville
Parkesburg
Pomeroy
Atglen
Marshallton
Doe Run
Cochranville
Unionville
Parkersville
Pocopson
Dilworthtown
Chadds Ford
Russellville
Chatham
Kennett Square
West Grove
Avondale
Centerville
Yorklyn
Elam
Benedict 400
Talleyville
Schuylkill River
Brandywine
READING
PENNSYLVANIA
4 LANES
3 LANES
2-6
2-4
4-8
4-6
5-7
5-8
7-10
7-12
1-3
1-4


75°30'
75°15'
75°00'
Sellersville
Tylersport
Green Lane
Layfield 320
Souderton
Doylestown
Buckingham
Gardenville
Aquetong
Pineville
Zieglersville
Harleysville
Hatfield
Chalfont
Wrightstown
Lansdale
Montgomeryville
Gloster 450
Eureka
Neshaminy
Hartsville
Limerick
Pottstown 311
Skippack
Kulpsville
North Wales
Perkiomen 280
Royersford
Worcester
Collegeville
Willow Grove NAS 369
Johnsville NAF 366
Richboro
BUCKS COUNTY
MONTGOMERY COUNTY
Southampton
Center Square
Phoenixville
Trooper
Ambler
Fort Washington
Willow Grove
Wings 350
Audubon
Valley Forge 250
NORRISTOWN
Hillside
Edge Hill
Abington
Somerton
Bridgeport
Valley Forge
Patco 350
Jenkintown
Rockledge
Boulevard 160
Northeast Philadelphia 106
Conshohocken
Chestnut Hill
Hillcrest
Ashbourne
Cheltenham
Bustleton
Devault
Philadelphia Mainline 310
St Davids
Malvern
Duffryn Mawr
Berwyn
Manayunk
Norberth
PHILADELPHIA
Malvern 460
Wyola
Ardmore
Palmyra
Newtown Square
Moorestown
Chester
Gradyville
Springton Reservoir
Jordantown
East Camden
Philadelphia Skyport 10
Stockton
Merchantville
Media
PHILADELPHIA
Camden 20
CAMDEN
West Collingswood
Collingswood
Darby
Gloucester
Audubon
Westmont
Mustin 16
Mount Ephraim
Philadelphia Southwest
Red Bank
Westville
Snow Hill
Haddon Heights
Elam
Benedict 400
Barrington 70
Echelon 100
North Woodbury
Billingsport
Buckman 90
Marcus Hook
CHESTER
Woodbury
Runnemede
Paulsboro
Almonesson 50
Clementon 100
Talleyville
Mount Royal
Woodbury
Blenheim
Clementon
West
DELAWARE
PENNSYLVANIA
NEW JERSEY
4-8
4-6
4
7-12
4-8
2-6
4-6
1-3
2-4
4-6
4-10
4-7
5-7
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2-6
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4-8
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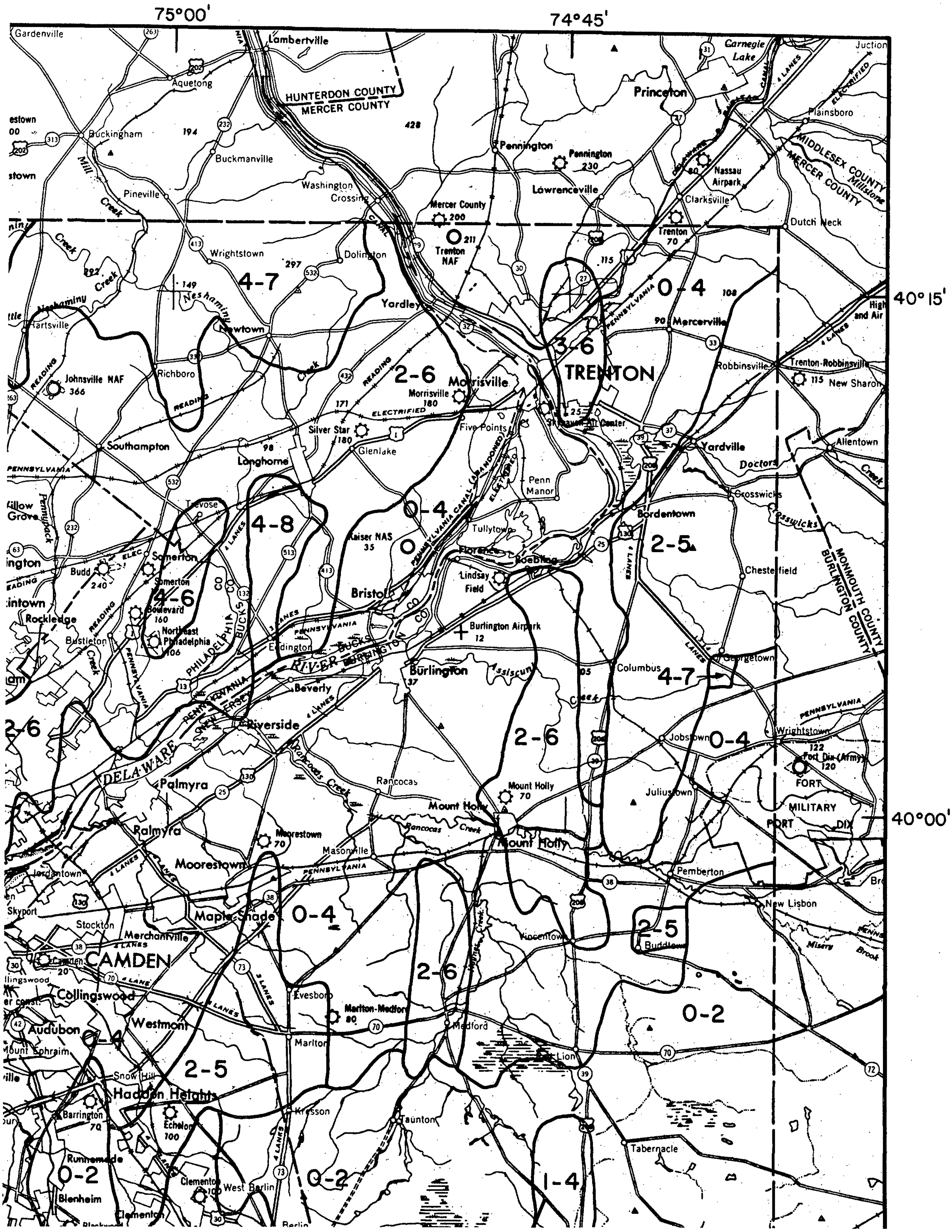
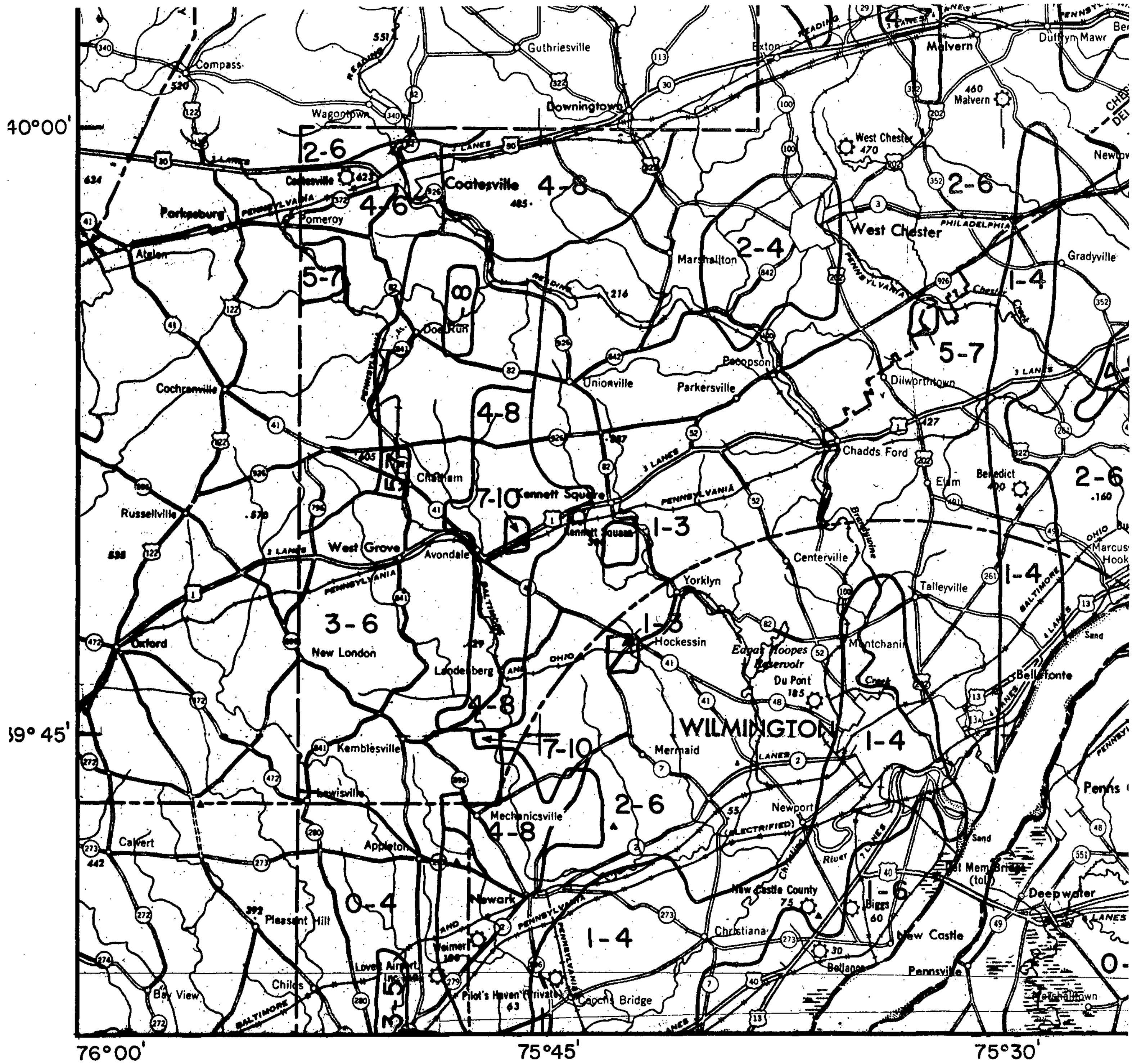
2-5
0-2

3



75°00'
74°45'
40°15'
40°00'
Gardenville
Lambertville
Aquetong
HUNTERDON COUNTY
MERCER COUNTY
Carnegie Lake
Princeton
Plainsboro
Buckingham
Buckmanville
194
428
Pennington
Pennington 230
MIDDLESEX COUNTY
MERCER COUNTY
Millstone
Nassau Airpark
Lawrenceville
Clarksville
Washington Crossing
Pineville
Mill Creek
Mercer County 200
211 Trenton NAF
Trenton 70
Dutch Neck
Wrightstown
297
Dolington
115
Neshaminy Creek
149
4-7
0-4
108
Yardley
Hartsville
Newtown
Mercerville
High and Air
3-6
Robbinsville
Trenton-Robbinsville
115 New Sharon
Johnsville NAF 366
Richboro
2-6
Morrisville
TRENTON
Morrisville 180
ELECTRIFIED
READING
Silver Star 180
Five Points
Southampton
Glenlake
Yardville
Allentown
98
Langhorne
Doctors Creek
PENNSYLVANIA
Penn Manor
Crosswicks
Bordentown
Trevose
4-8
0-4
Tullytown
Crosswicks
Raiser NAS 35
Florence
Roebling
2-5
MONMOUTH COUNTY
BURLINGTON COUNTY
Somerton
Budd 240
Somerton
Lindsay Field
Chesterfield
4-6
Bristol
Boulevard 160
Northeast Philadelphia 106
Rockledge
Bustleton
Burlington Airpark 12
Edgington
BUCKS CO
BURLINGTON CO
PHILADELPHIA CO
Columbus
Georgetown
4-7
Burlington 37
Assiscunk Creek
Beverly
Riverside
2-6
DELAWARE RIVER
PENNSYLVANIA
NEW JERSEY
Jobstown
0-4
Wrightstown
Fort Dix (Army) 120
FORT
MILITARY
FORT DIX
Palmyra
Rancocas
Rancocas Creek
Mount Holly 70
Mount Holly
Juliustown
Palmyra
Moorestown 70
Masonville
Moorestown
Pemberton
Jordantown
Skyport
New Lisbon
Stockton
Maple Shade
0-4
Merchantville
Vincentown
2-5
Budd Lake
Misery Brook
CAMDEN
Camden 20
Collingswood
2-6
Evesboro
Marlton-Medford 80
0-2
Audubon
Westmont
Marlton
Medford
Mount Ephraim
0-4
Lion
2-5
Snow Hill
Haddon Heights
Barrington 70
Echelon 100
Kresson
Taunton
Tabernacle
Runnemede
0-2
0-2
1-4
Blenheim
Clementon 100
West Berlin
Clementon
Berlin



BASE FROM TOPOGRAPHIC MAPS
OF THE U.S. SCALE 1/250,000

NEWARK
SALISBURY
WILMINGTON

AER(

CAMDEN-

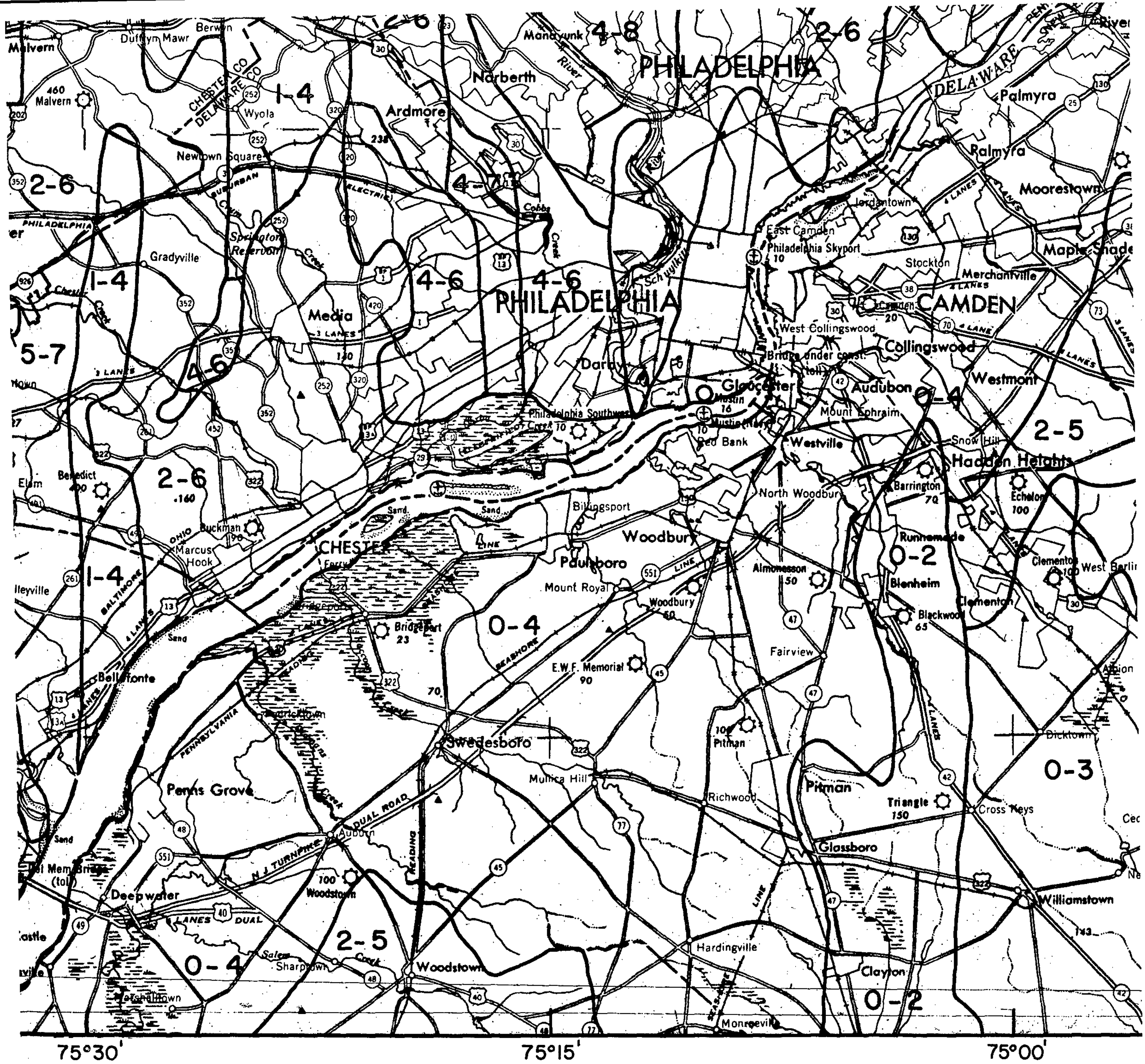
PENNSY

RADIOACTIVITY LEVELS IN HUNDREDS

SURVEYED BY EG&G, INC., WITH AI

4

PLATE I NORTH PART



SUGGESTE
25 counts/se

AERORADIOACTIVITY MAP (ARMS-II)

CAMDEN-DELAWARE VALLEY AREA, NEW JERSEY, PENNSYLVANIA, DELAWARE, AND MARYLAND

IN HUNDREDS OF COUNTS PER SECOND NORMALIZED TO 500 FT ABO'

C., WITH AIRCRAFT N702B

SEPTEMBER 4 - OCTOI

5

5 0 5 10

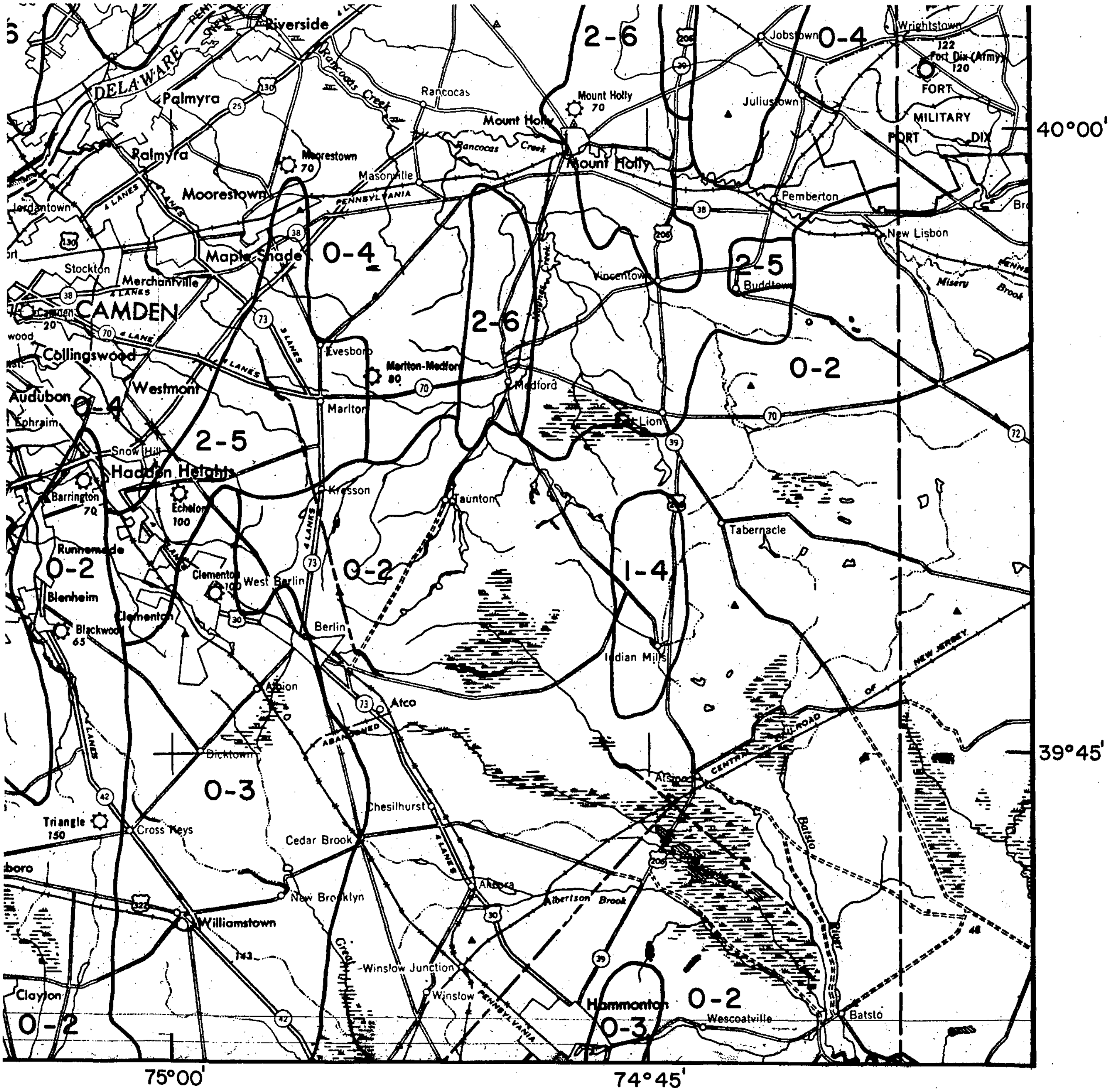
MILES

LIMIT OF

4-6 RADIOACT

2-3 AERORADI

RT



SUGGESTED CONVERSION FACTOR
25 counts/sec at 500 ft = 1 μr/hr at 3 ft

I)

JERSEY,

AND

D TO 500 FT ABOVE GROUND

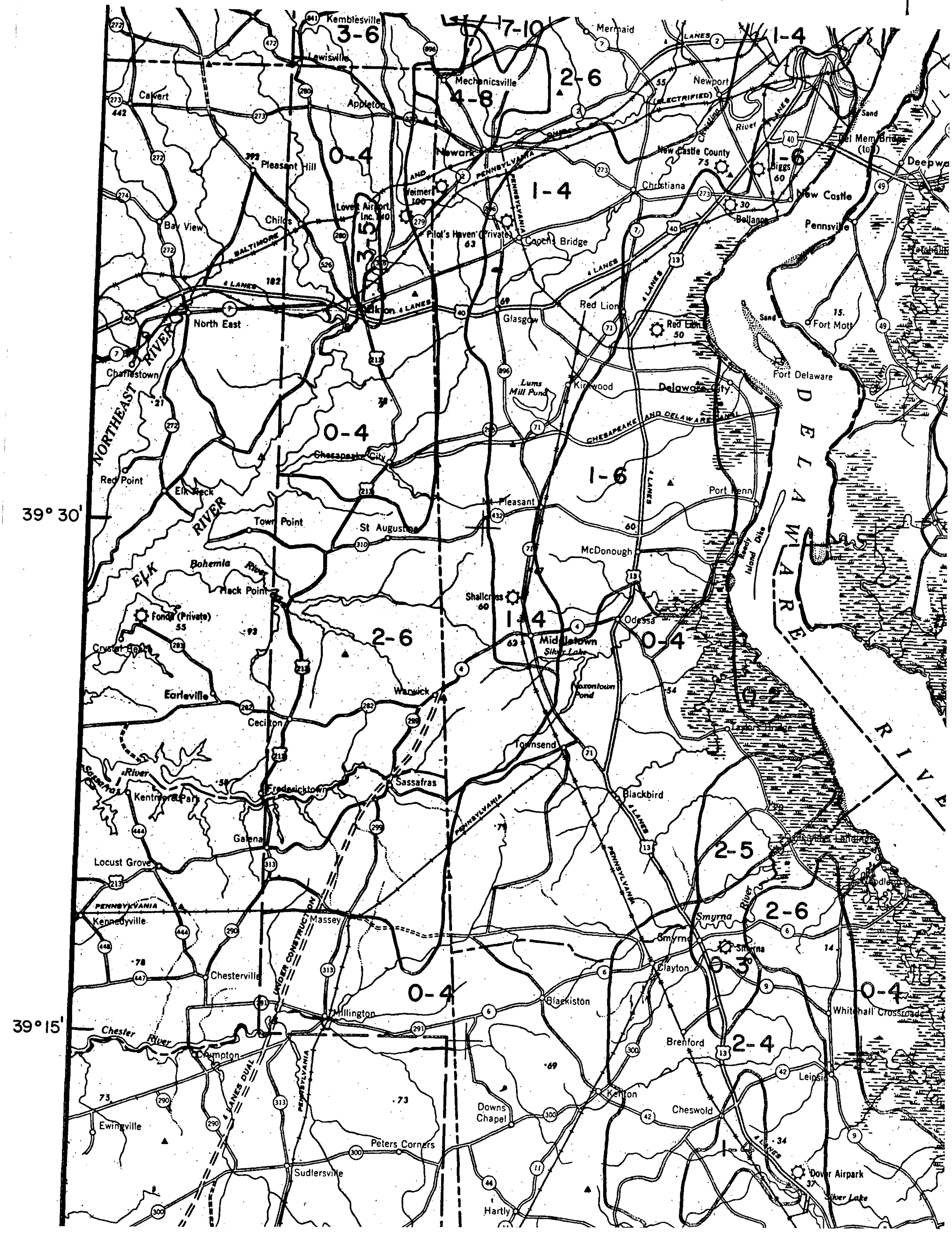
EPTEMBER 4 - OCTOBER 16, 1961

6

LIMIT OF SURVEYED AREA

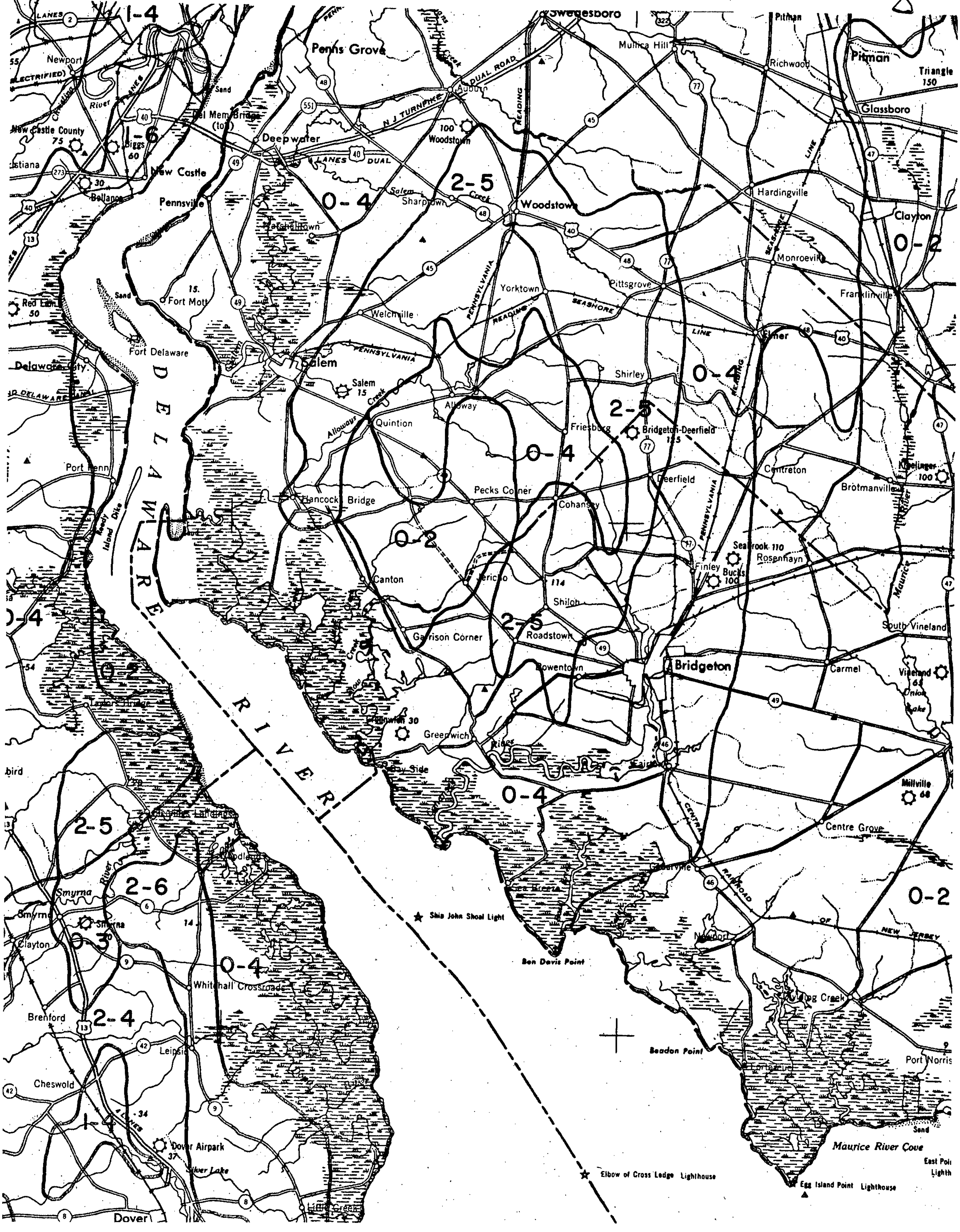
4-6 RADIOACTIVITY, 10^2 COUNTS/SEC

2-3 AERORADIOACTIVITY UNIT



Kemblesville
Lewisville
Mermaid
Newport
Mechanicsville
Calvert
Appleton
Newark
Pleasant Hill
New Castle County
Biggs
Del Mem Bridge (toll)
Deepwa
Christiana
New Castle
Weimer's
Lovett Airport, Inc.
Childs
Bay View
Pilot's Haven (Private)
Cooch's Bridge
Bellanca
Pennsville
Elkton
North East
Glasgow
Red Lion
Red Lion
Fort Mott
Charlestown
Lums Mill Pond
Kirkwood
Delaware City
Fort Delaware
NORTHEAST RIVER
CHESAPEAKE AND DELAWARE CANAL
Chesapeake City
Red Point
Elk Neck
ELK RIVER
Mt. Pleasant
Port Penn
DELAWARE RIVER
39° 30'
Town Point
St Augustine
McDonough
Bohemia River
Hack Point
Reedy Island Dike
Fonda (Private)
Shallcross
Odessa
Middletown
Silver Lake
Crystal Beach
Earleville
Warwick
Noxontown Pond
Cecilton
Taylors Bridge
Townsend
Sassafras River
Kentmore Park
Fredericktown
Sassafras
Blackbird
Galena
Locust Grove
Kennedyville
Massey
Smyrna
Smyrna River
Chesterville
WIDER CONSTRUCTION
Clayton
Millington
Blackiston
Whitehall Crossroads
39°15'
Chester River
Crumpton
Brenford
Leipsic
Kenton
Downs Chapel
Cheswold
Ewingville
Peters Corners
Dover Airpark
Sudlersville
Silver Lake
Hartly
PENNSYLVANIA
BALTIMORE AND OHIO
4 LANES
4 LANES DUAL
3-6
7-10
1-4
2-6
4-8
0-4
1-6
1-4
3-5
0-4
1-6
2-6
1-4
0-4
0-2
2-5
2-6
0-3
0-4
2-4
0-4

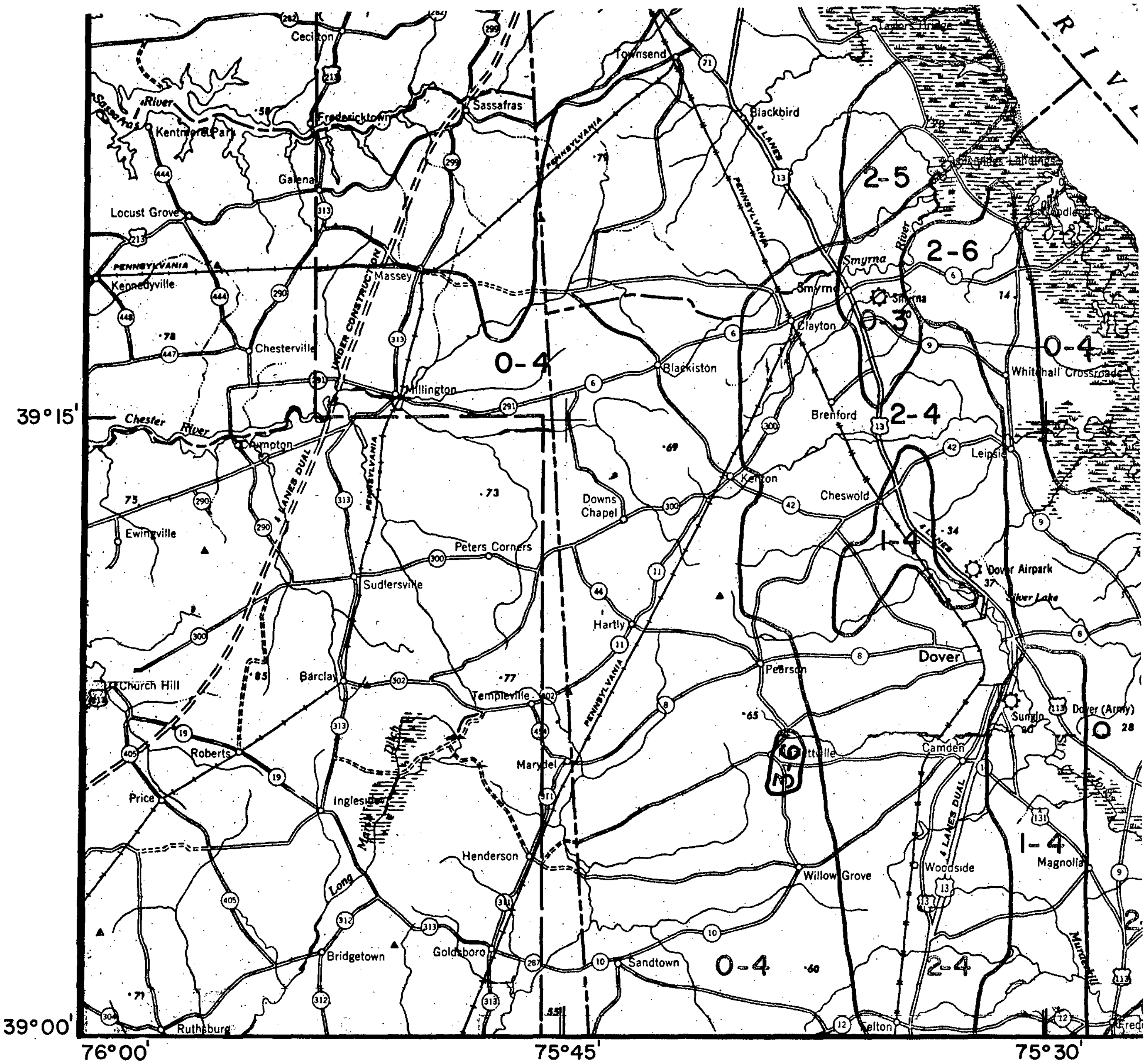
8



1-4
1-6
0-4
2-5
0-2
2-6
0-3
2-4
Newport
New Castle County 75
Biggs 60
New Castle
Bellanca 30
Pennsville
Del Mem Bridge (toll)
Deepwater
Penns Grove
Swedesboro
Mullica Hill
Richwood
Pitman
Triangle 150
Glassboro
Auburn
N J TURNPIKE
DUAL ROAD
Woodstown 100
Woodstown
Sharptown
Salem Creek
Hardingville
Clayton
Monroeville
Pittsgrove
Franklinville
Yorktown
Fort Mott
Red Lion 50
Fort Delaware
Welchville
Delaware City
Salem
Salem 15
Elmer
Shirley
Alloway
Quinton
Alloways Creek
Friesburg
Bridgeton-Deerfield 135
Port Penn
Deerfield
Centreton
Kroelinger 100
Brotmanville
Hancocks Bridge
Pecks Corner
Cohansey
Seabrook 110
Rosenhayn
Finley
Bucks 100
Canton
Jericho
Shiloh
Garrison Corner
Roadstown
South Vineland
Bowentown
Bridgeton
Carmel
Vineland 64
Union Lake
Greenwich 30
Greenwich
Bay Side
Millville 68
Centre Grove
Smyrna
Smyrna 30
Clayton
Whitehall Crossroads
Brenford
Leipsic
Cheswold
Dover Airpark 37
Silver Lake
Dover
Little Creek
Ship John Shoal Light
Ben Davis Point
Newport
Beadon Point
Port Norris
Maurice River Cove
Egg Island Point Lighthouse
Elbow of Cross Ledge Lighthouse
DELAWARE RIVER
PENNSYLVANIA READING SEASHORE LINE
CENTRAL RAILROAD OF NEW JERSEY

9

0-3
0-2
0-3
0-2
0-3
0-3
0-2
0-3
0-3
1-3
0-2
0-2
1-3
39°
39°
Pitman
Triangle 150
Cross Keys
Glassboro
Williamstown
Clayton
Janvier
Franklinville
Malaga
Newfield
Downstown 120
Klinger 100
Brotmanville
Landisville
Vineland
South Vineland
Carmel
Vineland 65
Union Lake
Oliver 50
Millville
Millville 68
Centre Grove
Port Elizabeth
Haleyville
Port Norris
Maurice River Cove
East Point Lighthouse
Island Point Lighthouse
Sand
Delmont
Eldora
Dennisville
South Seaville
Clermont
Sea Isle City
Ludlam Bay
Ludlam Beach Light
Strathmere
Corson Inlet
Seaville
Peck Beach
Ocean City
Petersburg
Woodbine
Woodbine 39
Belleplain
Tuckahoe
Hunters Mill
Manumuskin
Cumberland
Risley
Estell Manor
English Creek
Mays Landing
McKee City
Atlantic City (Navy)
Pomona
Germania
Laureldale
Egg Harbor City
Weymouth
Elwood
Weekstown
Green Bank
Batsto
Wescoatville
Hammonton
Alsop
Chesilhurst
Cedar Brook
New Brooklyn
Ancora
Albertson Brook
Winslow Junction
Winslow
Berryland
Richland
East Vineland
Cavoli 100
Milmay
Mullica
Great Egg Harbor Bay
Rainbow Islands
Maurice River
Manumuskin River
Manantico Creek
Great Egg Harbor River
CENTRAL RAILROAD OF NEW JERSEY
PENNSYLVANIA
READING
SEASHORE LINE
4 LANES



BASE FROM TOPOGRAPHIC MAPS
OF THE U.S. SCALE 1/250,000

NEWARK
SALISBURY
WILMINGTON

AE

CAMDEN

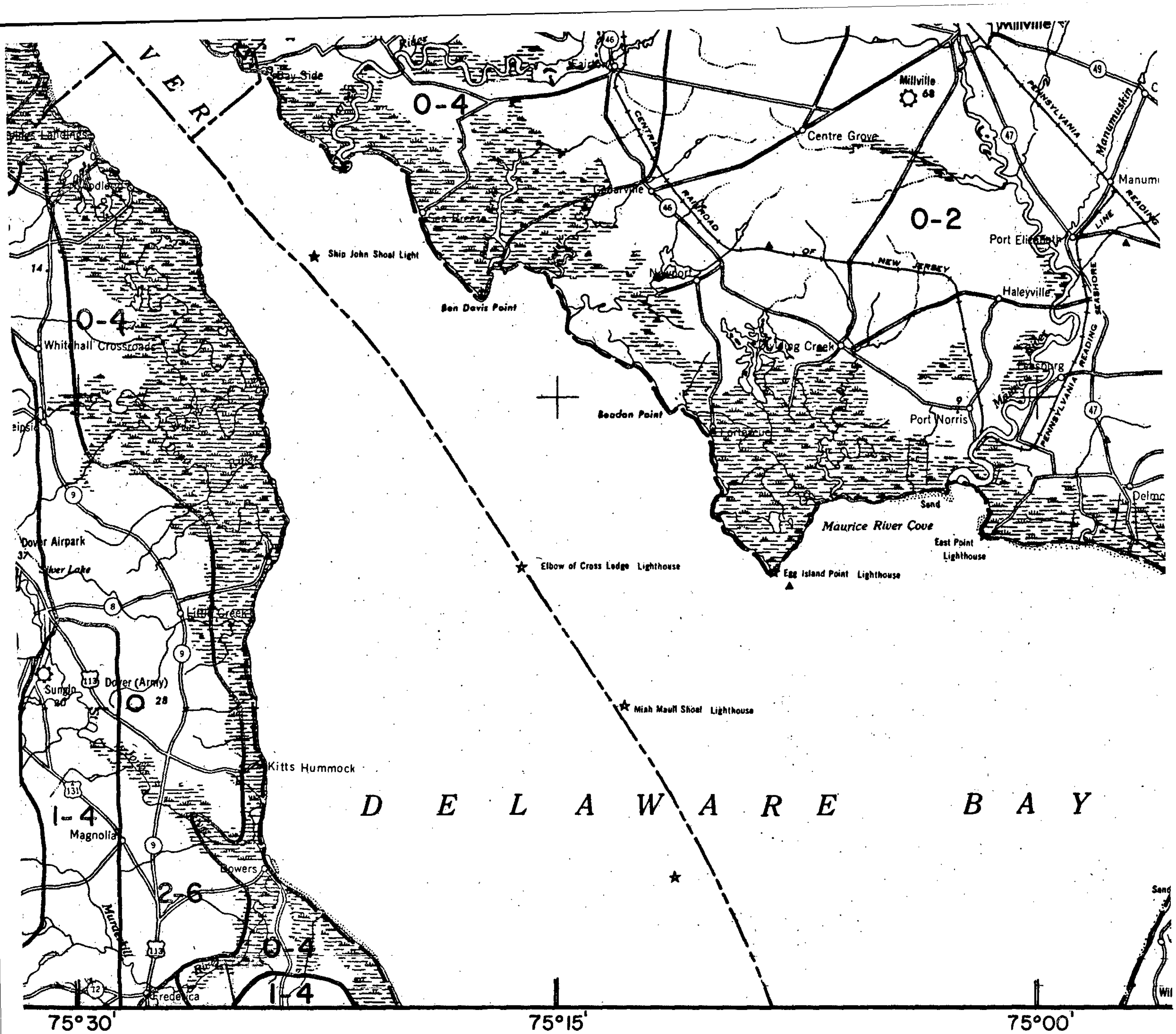
PENN

RADIOACTIVITY LEVELS IN HUNDR

SURVEYED BY EG&G, INC., WITH

10

PLATE 2 CENTER PART



SUGGESTE
25 counts/se

AERORADIOACTIVITY MAP (ARMS-II)

CAMDEN-DELAWARE VALLEY AREA, NEW JERSEY, PENNSYLVANIA, DELAWARE, AND MARYLAND

IN HUNDREDS OF COUNTS PER SECOND NORMALIZED TO 500 FT ABO

C., WITH AIRCRAFT N702B

SEPTEMBER 4 - OCTO

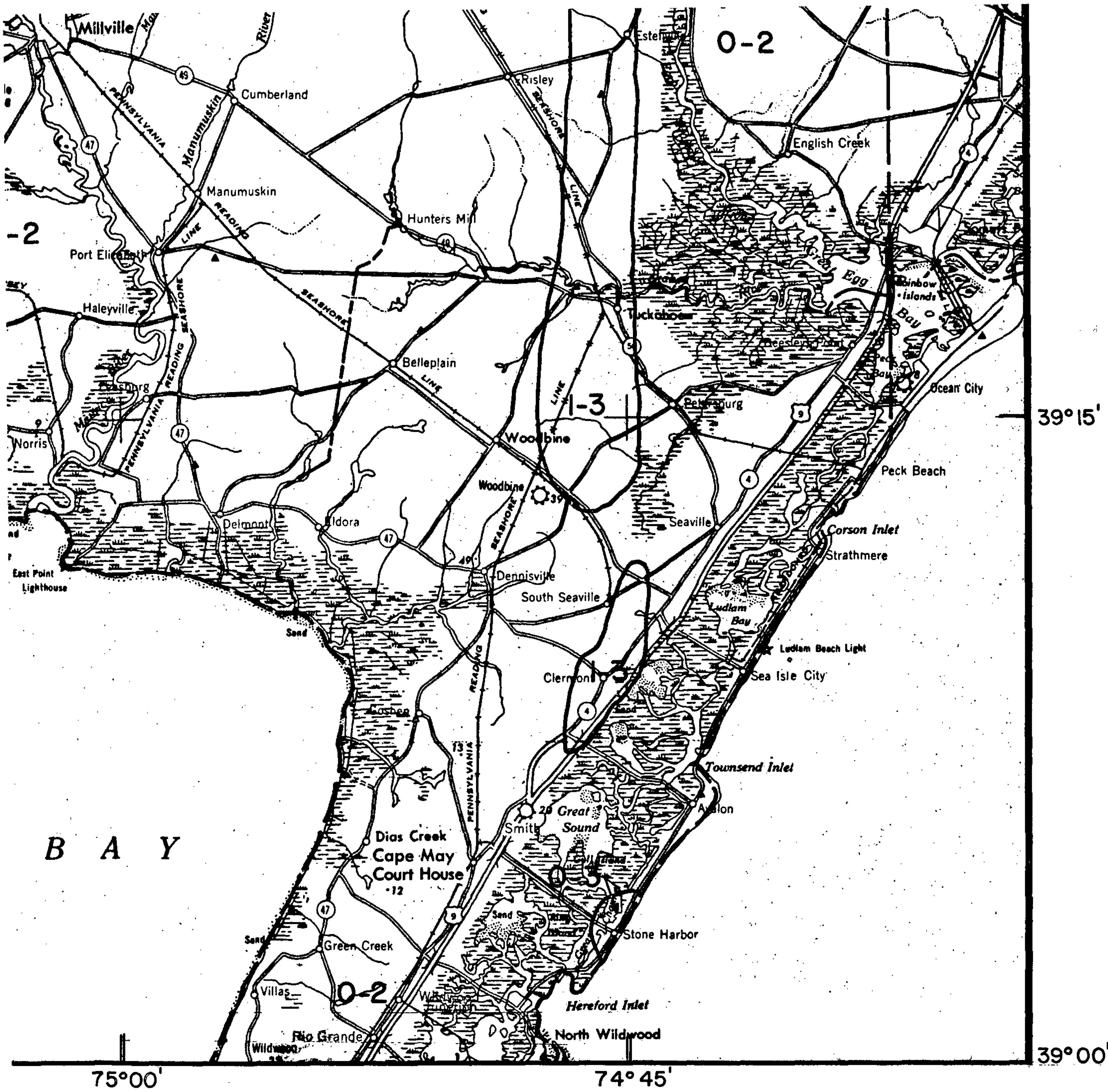
5 0 5 10
MILES

LIMIT OF

4-6 RADIOACT

2-3 AERORADI

RT



SUGGESTED CONVERSION FACTOR
25 counts/sec at 500 ft = $1 \mu r$/hr at 3 ft

SEY,

O 500 FT ABOVE GROUND

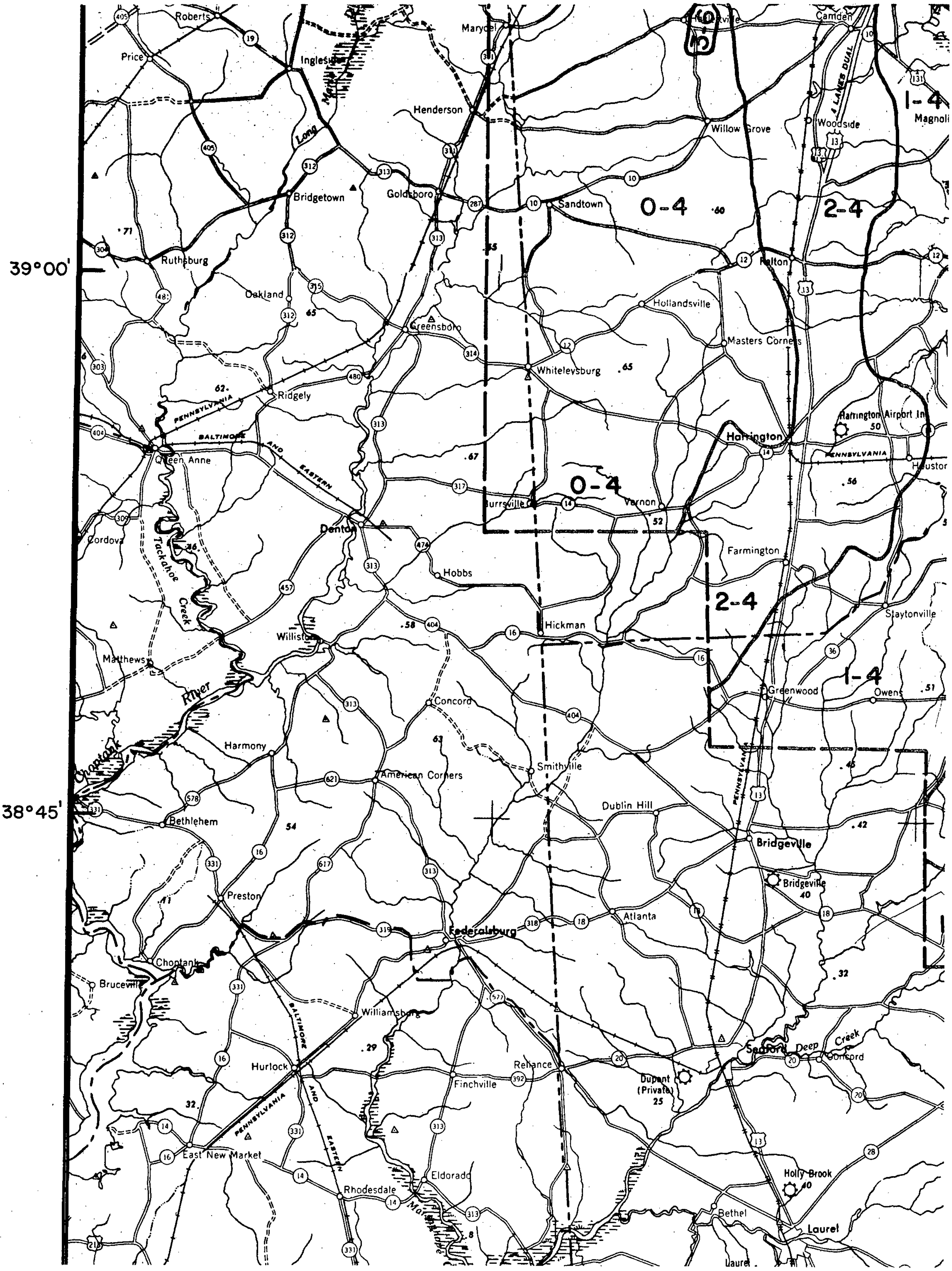
EMBER 4 - OCTOBER 16, 1961

LIMIT OF SURVEYED AREA

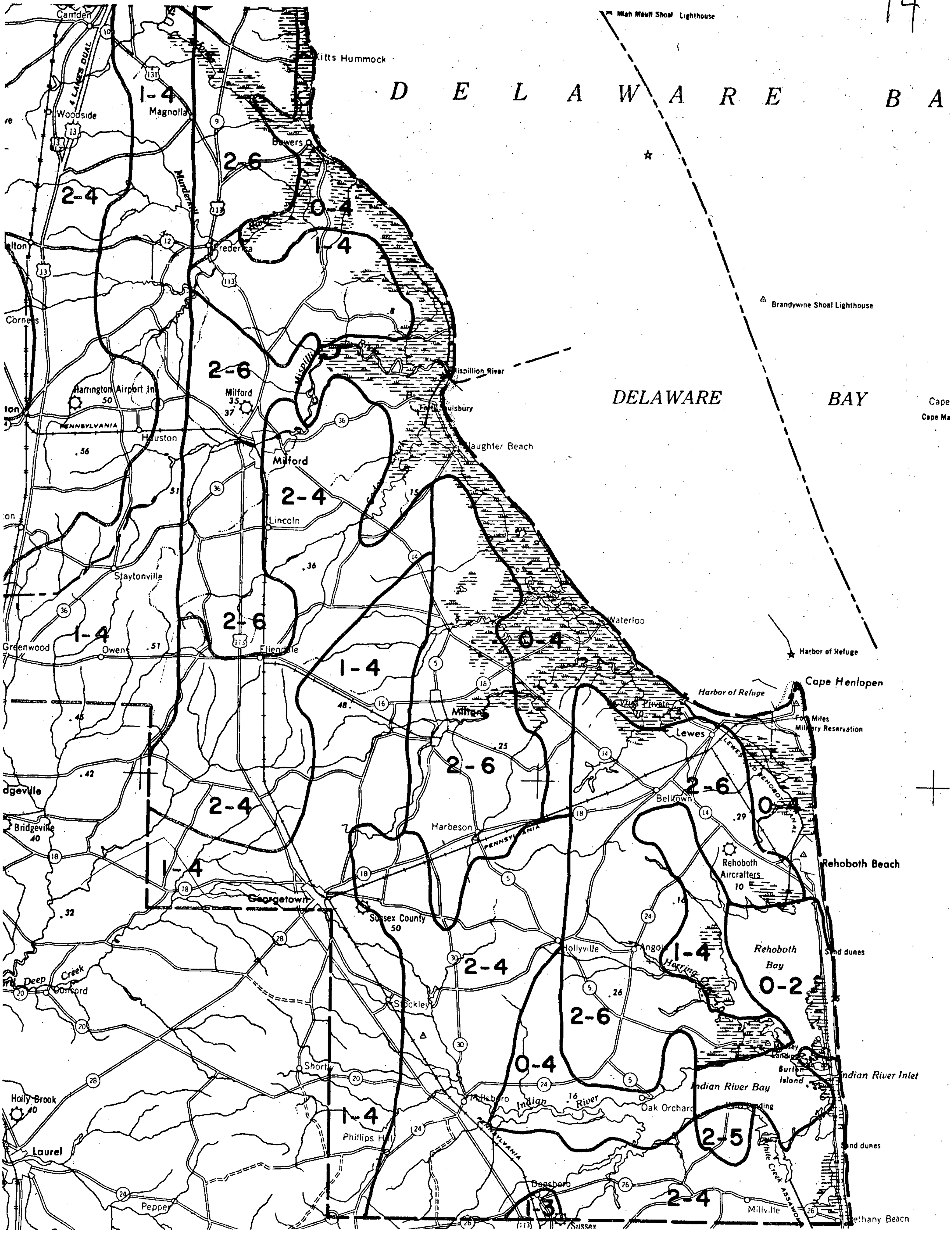
4-6 RADIOACTIVITY, 10^2 COUNTS/SEC

2-3 AERORADIOACTIVITY UNIT

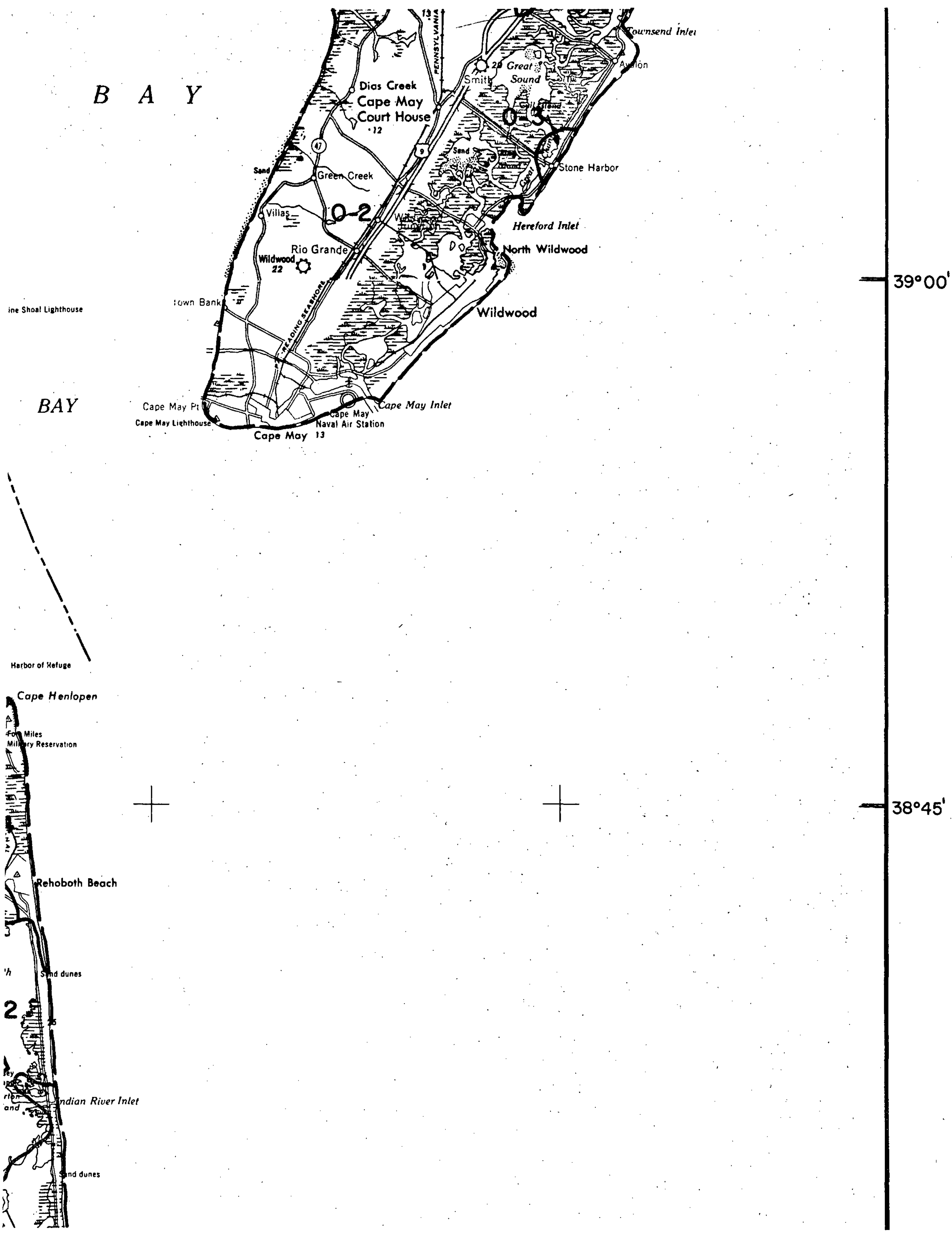
12

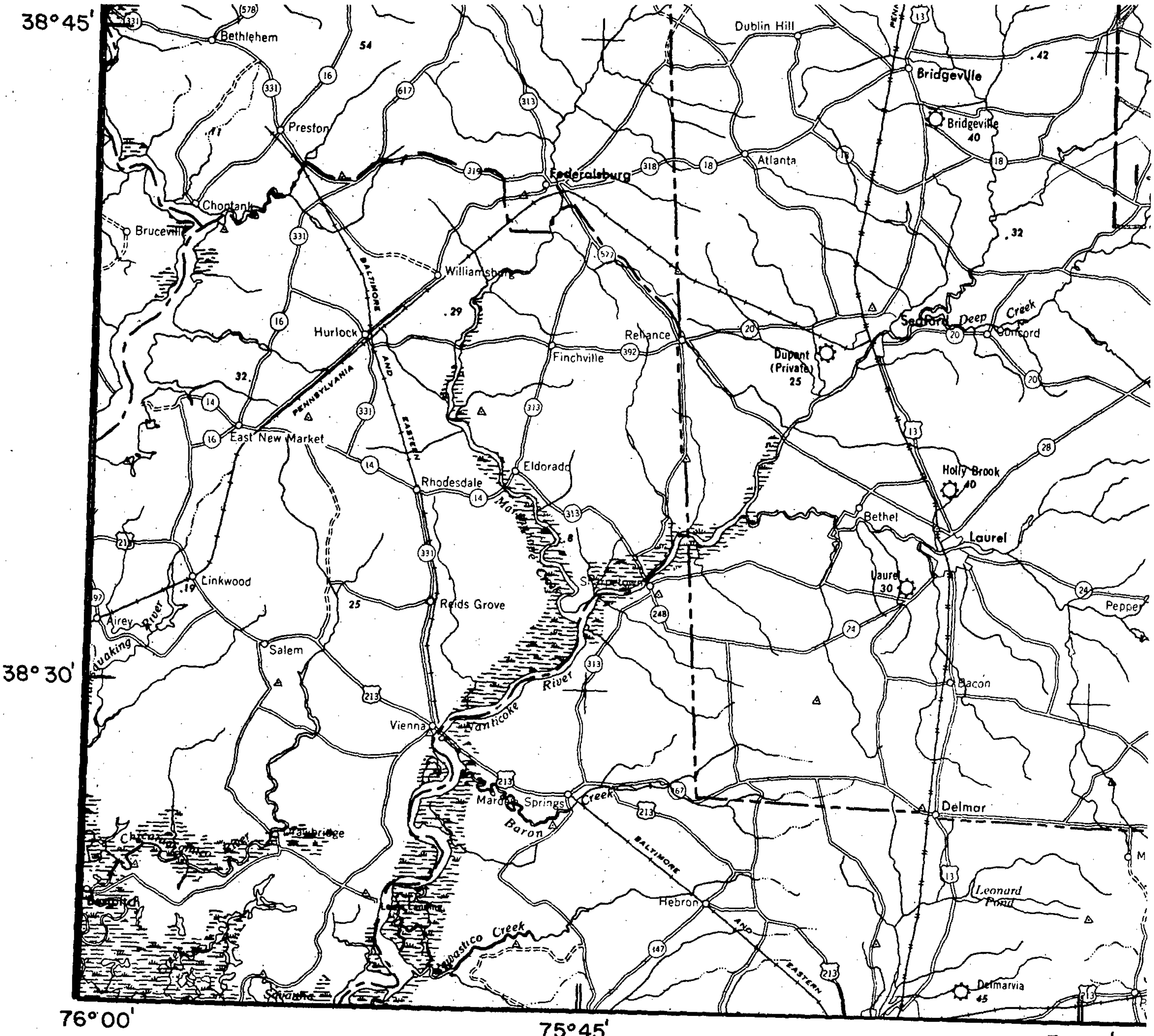


39°00'
38°45'
Roberts
Price
Ingleside
Marydel
Henderson
Camden
Willow Grove
Woodside
Magnoli
4 LANES DUAL
1-4
0-4
2-4
Bridgetown
Goldsboro
Sandtown
Ruthsburg
Felton
Oakland
Hollandsville
Greensboro
Masters Corners
Whiteleysburg
Ridgely
Harrington Airport Inc
Harrington
PENNSYLVANIA
BALTIMORE AND EASTERN
Queen Anne
Houston
Burrsville
Vernon
Cordova
Denton
Farmington
Tuckahoe Creek
Hobbs
Hickman
Staytonville
Williston
Matthews
River
Choptank
Greenwood
Owens
Concord
Harmony
Smithyille
American Corners
Dublin Hill
Bethlehem
Bridgeville
Preston
Atlanta
Federalsburg
Choptank
Bruceville
Williamsburg
Seaford
Deep Creek
Concord
Hurlock
Reliance
Dupont (Private)
Finchville
East New Market
Eldorado
Holly Brook
Rhodesdale
Marshyhope
Bethel
Laurel



DELAWARE BA
DELAWARE BAY
Cape
Cape Ma
Kitts Hummock
Brandywine Shoal Lighthouse
Harbor of Refuge
Cape Henlopen
Fort Miles Military Reservation
Rehoboth Beach
Rehoboth Bay
Sand dunes
Indian River Inlet
Indian River Bay
Burton Island
Bethany Beach
Millville
Camden
Woodside
Magnolia
Bowers
Frederica
Corners
Harrington Airport Inc
Milford
Houston
Lincoln
Staytonville
Greenwood
Owens
Ellendale
Mispillion River
Slaughter Beach
Waterloo
Milton
Lewes
Belltown
Harbeson
Rehoboth Aircrafters
Georgetown
Sussex County
Hollyville
Angola
Herring Creek
Stockley
Shortly
Millsboro
Indian River
Oak Orchard
Phillips Hill
Dagsboro
Laurel
Pepper
Holly Brook
Concord
Deep Creek
Bridgeville
Sussex
White Creek
PENNSYLVANIA
4 LANES DUAL
1-4
2-4
2-6
0-4
0-2
2-5
1-3


Townsend Inlet
Avalon
Great Sound
Smith
PENNSYLVANIA
B A Y
Dias Creek
Cape May Court House
12
47
9
Stone Harbor
Sand
Green Creek
Villas
O-2
O-3
Hereford Inlet
North Wildwood
Rio Grande
Wildwood 22
39°00'
Town Bank
ine Shoal Lighthouse
Wildwood
READING SEASHORE
BAY
Cape May Pt
Cape May Inlet
Cape May Lighthouse
Cape May Naval Air Station
Cape May
13
Harbor of Refuge
Cape Henlopen
38°45'
Rehoboth Beach
Sand dunes
2
Indian River Inlet
Sand dunes



BASE FROM TOPOGRAPHIC MAPS
OF THE U.S. SCALE 1/250,000

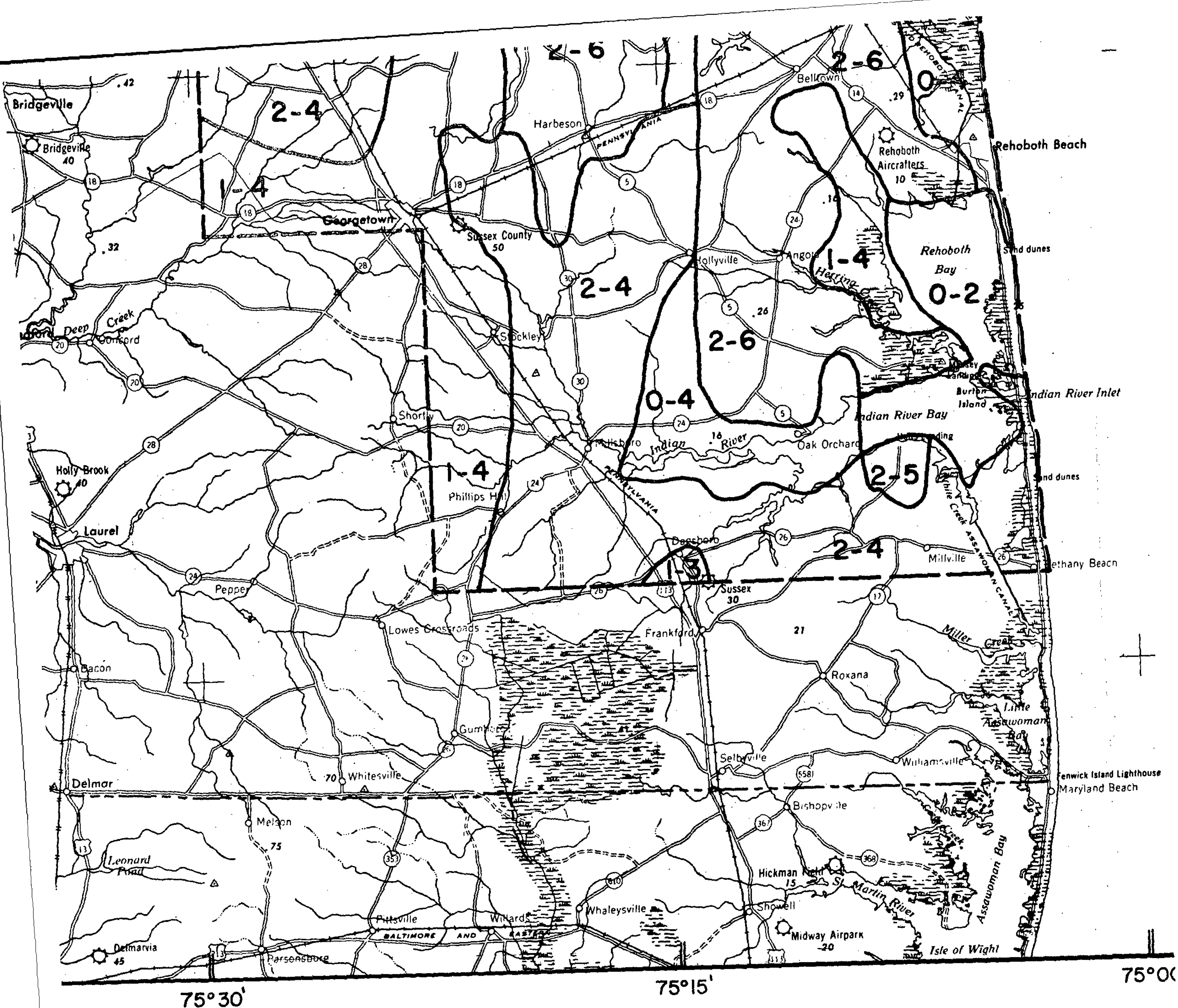
NEWARK
SALISBURY
WILMINGTON

CAMD
PE

RADIOACTIVITY LEVELS IN HUN
SURVEYED BY EG&G, INC., WIT

16

PLATE 3 SOUTH PART



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25

AERORADIOACTIVITY MAP (ARMS-II)

CAMDEN-DELAWARE VALLEY AREA, NEW JERSEY, PENNSYLVANIA, DELAWARE, AND MARYLAND

:VELS IN HUNDREDS OF COUNTS PER SECOND NORMALIZED TO 500 F'

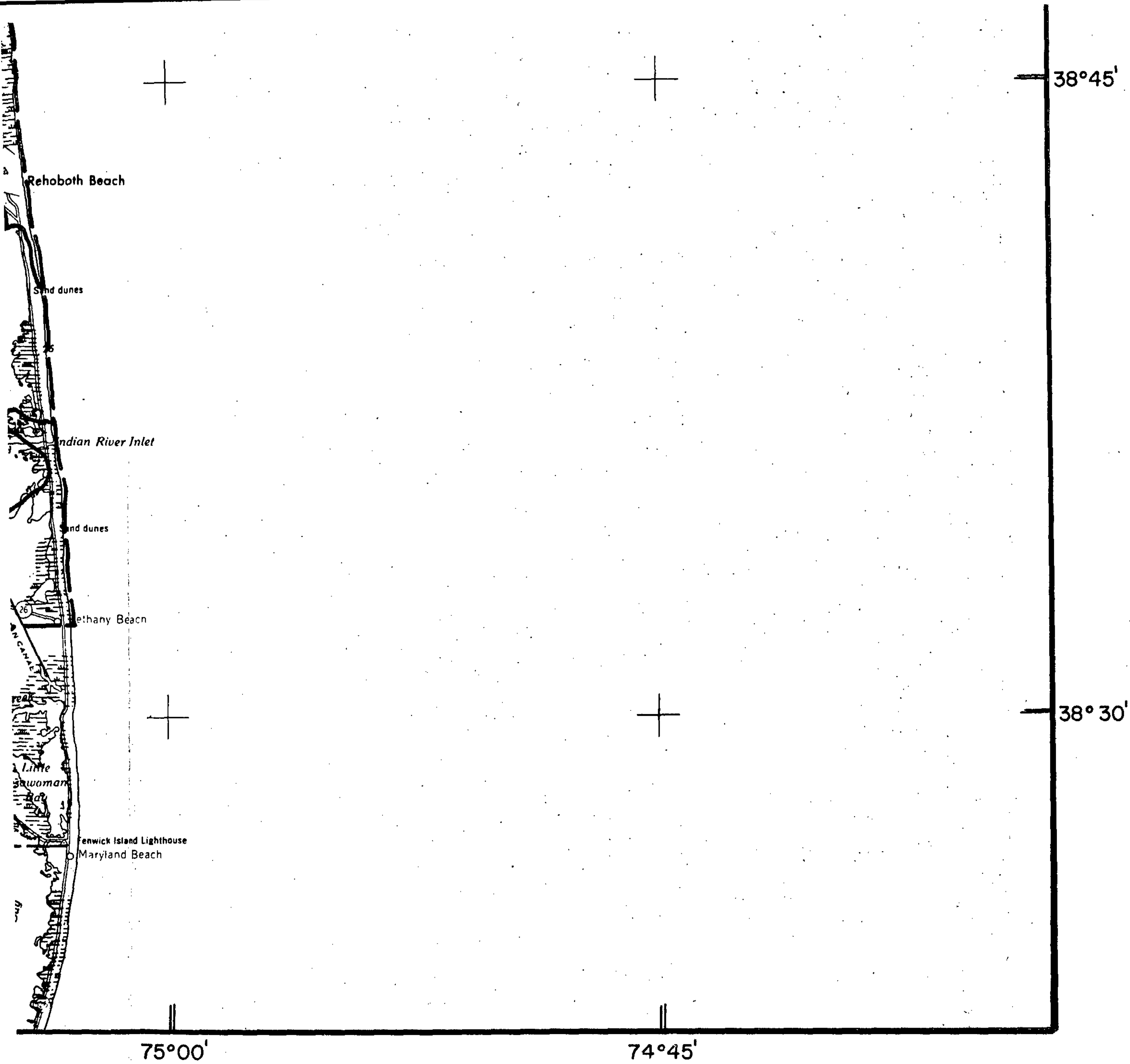
;&G, INC., WITH AIRCRAFT N702B

SEPTEMBER 4

17

4-6 F
2-3

PART



SUGGESTED CONVERSION FACTOR
25 counts/sec at 500 ft = 1 μr/hr at 3 ft

)

:RSEY,
ND

TO 500 FT ABOVE GROUND
PTEMBER 4 - OCTOBER 16, 1961

18

LIMIT OF SURVEYED AREA
4-6 RADIOACTIVITY, 10^2 COUNTS/SEC
2-3 AERORADIOACTIVITY UNIT